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Effectiveness of a Solder Fume Tip Extraction System: Effects of Tube Diameter, Air Flow Rate and Air Flow Velocity

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EXECUTIVE SUMMARY

OBJECTIVES

To investigate the effects of tube diameter, extraction flow rate and air flow velocity on the effectiveness of a solder fume tip extraction system.

MAIN FINDINGS

Over the range of parameters considered in this investigation (extraction tube apertures ranging from 3 mm to 9 mm diameter, extraction flow rates ranging from 22 l/min to 44 l/min) the following findings are evident:

1. Increasing the extraction flow rate shows a measurable, but non-linear increase in extraction effectiveness.
2. Changes in aperture size or air flow velocity have negligible effect on extraction effectiveness unless they result in corresponding changes in extraction flow rate.

MAIN RECOMMENDATIONS

The extraction flow rate is the most important aspect of a solder fume tip extraction system, and should therefore be the prime consideration when improvements to existing systems are required.

1 INTRODUCTION

Solder used in the manufacture of electronic components is typically rosin (colophony) cored, comprising a metal alloy binary eutectic mixture of approximate proportions 60% tin and 40% lead surrounding an internal core of rosin based flux of 2-3% weight [1][2]. The flux prevents oxidation of components at the elevated temperatures required for soldering, removes existing oxides and sulphides from the surface of the components, and reduces the surface tension of the molten solder [2].

At temperatures above the melting point of the solder (183°C), and particularly greater than 200°C, thermal decomposition of the flux occurs producing rosin-based solder flux fume, which is a respiratory sensitizer known to cause occupational asthma [3,4,5,6] and possibly allergic dermatitis [7]. Quantitative measurements of the fume produced are known to depend on thickness of the solder, metal-flux ratio, flux composition and solder temperature [8].

Figure 1.1: Soldering Iron with Tip Extraction Pipe as Supplied by Weller

Investigations into various types of fume extraction systems available commercially have been undertaken previously at HSL [9,10], in which the tip extraction method was shown to be most effective. Tip extraction is performed via a stainless steel tube attached to the soldering iron in such a position that the tip of the tube is in line with end of the soldering iron tip and a perpendicular distance of approximately 5 mm away from it (see Figure 1.1). This allows maximum fume recovery without unduly compromising the temperature or the accessibility of the iron. The metal tube is then attached via a length of rubber tube to an extraction unit that exhausts the fume via suitable filters.

A previous HSL investigation (11,12) has shown the effectiveness of this method of fume extraction to be improved over that of a commercially available system by increasing the tube diameter and extraction flow rate. This investigation is designed to further determine the dependency of the effectiveness of a solder fume tip extraction system on tube aperture diameter, extraction flow rate and air flow velocity.

2 EXPERIMENTAL PROCEDURE

The equipment used in this investigation and the relevant specifications are shown in Table 2.1.

Table 2.1: Equipment Specifications.

Soldering Iron	Weller 80 W
Iron Temperature Control Unit	Weller PUD 80
Solder	Multi-core Crystal 502, 60/40, 3 Core
Soldering Iron Temperature	400°C
Aperture of Extraction Tubes Investigated (± 0.5 mm)	3, 5, 7, 9
Extraction Flow Rates Investigated (± 0.5 l/min)	22, 30, 38, 44

These investigations were performed following the procedure laid out in reference [11] utilising the SKC Split 2 to monitor the solder fume levels. The tests were performed in the purpose built enclosure shown in Figure 2.1. A funnel was attached to the sensing head of the Split 2 and positioned directly above the soldering iron tip to capture as much of the escaping fume as possible.

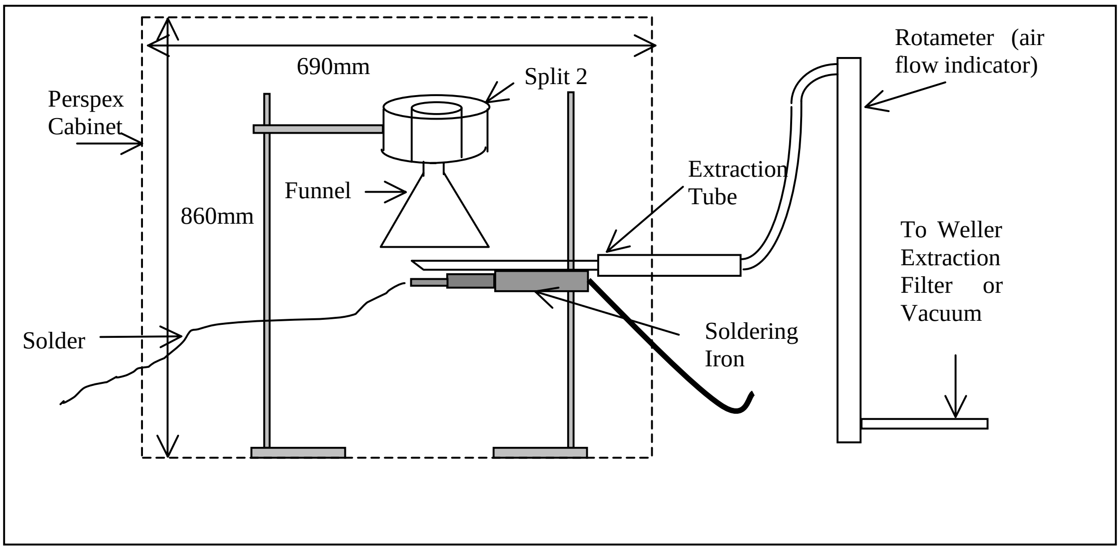

Figure 2.1: Experimental Set Up to Investigate the Effectiveness of Each Extraction System.

This investigation was only concerned with the change in total fume due to changes in conditions. Comparisons to 8-hour time weighted average (TWA) and the short term exposure limit (STEL) were not required as part of this procedure. Thus, as previous investigations [11] have shown the Split 2 to operate linearly when detecting solder fume concentration, the actual concentrations detected by the Split 2 monitor (calibrated to Arizona road dust in units of mg/m^3) were utilised in all analysis throughout this investigation.

The extraction effectiveness of each of the 4 extraction tubes of apertures measuring 3 mm, 5 mm, 7 mm and 9 mm for 4 different extraction flow rates of 22 l/min, 30 l/min, 38 l/min and 44 l/min were investigated and compared.

3 RESULTS

3.1 EFFECT OF CHANGING EXTRACTION TUBE APERTURE AT CONSTANT EXTRACTION FLOW RATE

Changes in extraction effectiveness due to changes in aperture diameter were observed and compared at each of 4 different extraction flow rates of 22 l/min, 30 l/min, 38 l/min and 44 l/min.

The average levels of fume detected as a function of extraction tube aperture are shown in Table 3.1 and Figure 3.1 below.

Table 3.1: Mean TWA of Colophony Fume Detected as a Function of Extraction Tube Aperture Diameter at Each Extraction Flow Rate

Tube Aperture (mm)	Fume Detected (mg/m^3)			
	22 l/min Ave	30 l/min Ave	38 l/min Ave	44 l/min Ave
3	0.374	0.371	0.028	0.116
5	0.593	0.452	0.170	0.153
7	0.640	0.219	0.112	0.134
9	0.443	0.422	0.322	0.102

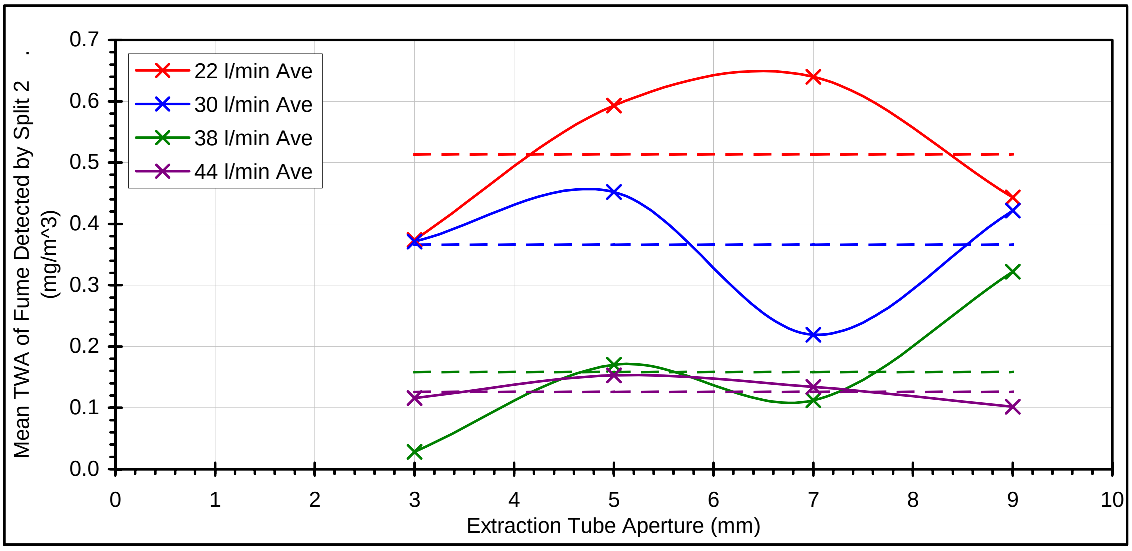

Figure 3.1: Mean TWA of Colophony Fume Detected as a Function of Extraction Tube Aperture Diameter at Each Extraction Flow Rate

Figure 3.1 shows the change in the level of detected fume (fume escaping the influence of the extraction tube) at each extraction flow rate to be apparently random as the tube diameter increases. The random results about the mean levels (shown as dotted lines in Figure 3.1) may be due to the unpredictable directional nature of the fume produced as the solder comes into contact with the soldering iron tip as experienced in previously documented investigations [11], and possible slight variations in the extraction flow rate throughout the experiments as the colophony deposits are formed in, and removed from, the extraction system.

A general increase in extraction effectiveness with increase in extraction flow rate at each tube diameter is suggested by the trend towards lower levels of fume detected by the Split 2. This relationship is investigated further in the following sub-section.

3.2 EFFECT OF CHANGING EXTRACTION FLOW RATE AT CONSTANT EXTRACTION TUBE APERTURE

As expected from previous investigations [11], there is a general trend to higher extraction effectiveness as the extraction flow rate is increased for each size of tube aperture. However, no direct proportionality is evident from the graph (Figure 3.2) or the data (Table 3.1). This again may be due to the unpredictable directional nature of the fume and possible slight variations in the extraction flow rate throughout the experiments as described in the previous sub-section

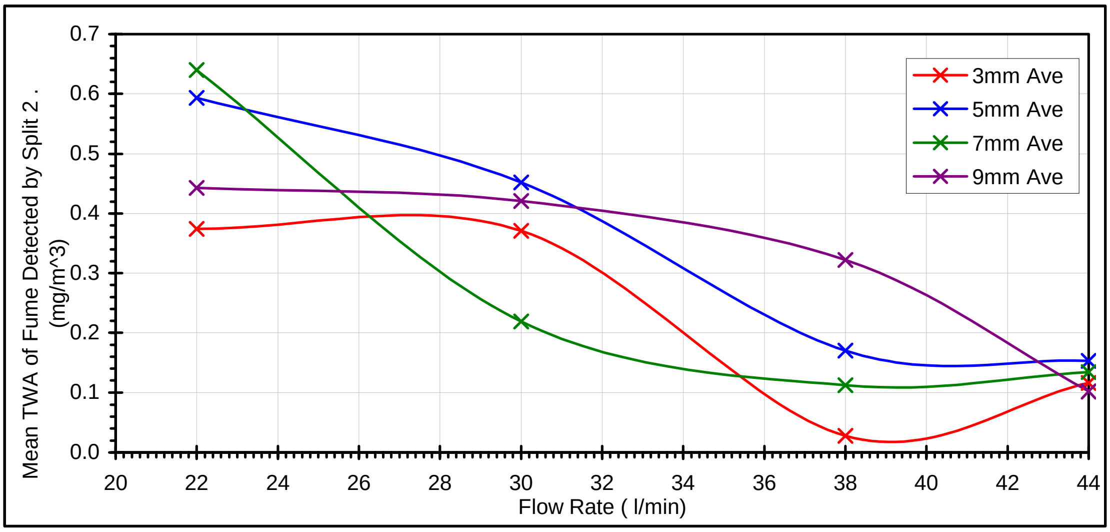

Figure 3.2: Mean TWA Of Colophony Fume Detected as a Function of Extraction Flow Rate at Each Extraction Tube Aperture Diameter

3.3 EFFECT OF CHANGING AIR FLOW VELOCITY

Air velocity at the extraction tube aperture and extraction flow rate through the extraction system are interdependent, the proportionality being determined by the size of the aperture as shown in Equation (1).

$$\text{air flow velocity(m/s)} = \frac{\text{extraction flow rate (l/min)}}{1000 \times \text{aperture area (m}^2) \times 60} \qquad \text{Equ (1)}$$

Thus the effect on the extraction effectiveness as a function of airflow velocity at the extraction tube tip can be determined from the experimental results obtained in the previous subsections.

The air flow velocity will decrease or increase as the aperture or the flow rate is increased in line with Equation (1). The air flow velocities at each extraction tube aperture and each extraction flow rate are shown in Table 3.2.

Table 3.2: Mean TWA of Colophony Fume Detected as a Function of Air Flow Velocity at Each Extraction Tube Aperture Diameter

3 mm Aperture		
Air Velocity at Tip (m/s)	Ave Fume Detected (mg/m^3)	Extraction Flow Rate (l/min)
51.87	0.374	22
70.74	0.371	30
89.60	0.028	38
103.75	0.116	44
5 mm Aperture		
Air Velocity at Tip (m/s)	Ave Fume Detected (mg/m^3)	Extraction Flow Rate (l/min)
18.67	0.593	22
24.46	0.452	30
32.26	0.170	38
37.35	0.153	44
7 mm Aperture		
Air Velocity at Tip (m/s)	Ave Fume Detected (mg/m^3)	Extraction Flow Rate (l/min)
9.53	0.640	22
12.99	0.219	30
16.46	0.112	38
19.06	0.134	44
9 mm Aperture		
Air Velocity at Tip (m/s)	Ave Fume Detected (mg/m^3)	Extraction Flow Rate (l/min)
5.76	0.443	22
7.86	0.421	30
9.96	0.322	38
11.53	0.102	44

Re-plotting Figure 3.1 with extraction effectiveness as a function of these air flow velocities at each extraction flow rate, gives the same random effects, as shown in Figure 3.3.

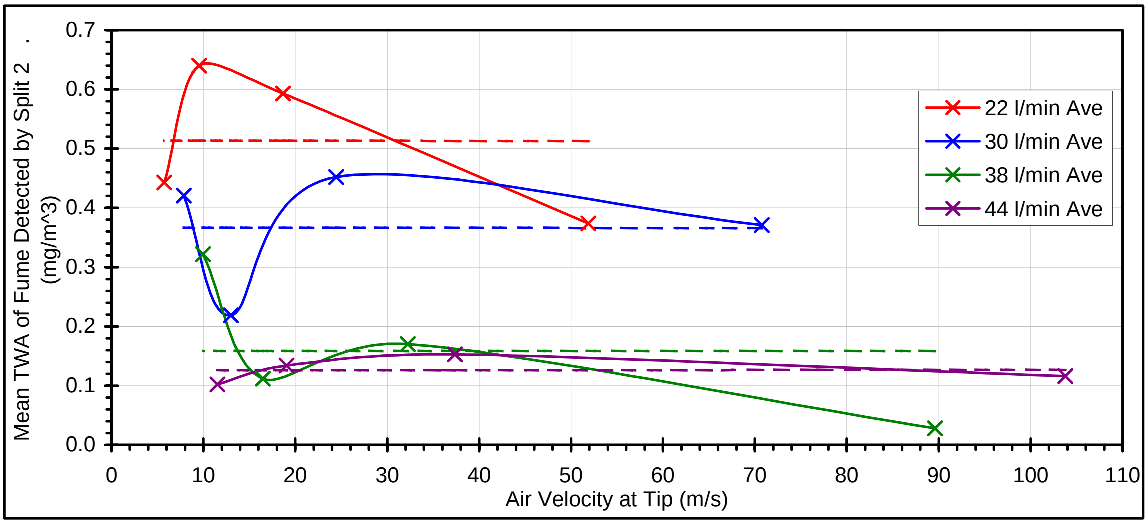

Figure 3.3: Mean TWA of Colophony Fume Detected as a Function of Air Flow Velocity at Each Extraction Flow Rate

Changes in air flow velocity seem to have no predictable effect on extraction effectiveness when the extraction flow rate remains constant. This may be due to the fact that, even though the fume is being extracted from the work-piece at a higher velocity, the area over which the extraction is effective is reduced, thus the actual volume of fume extracted per unit time is unchanged.

Re-plotting Figure 3.2 with extraction effectiveness as a function of air flow velocities at each aperture diameter, a similar trend towards higher extraction effectiveness as the air flow velocity is increased is evident, as shown in Figure 3.4.

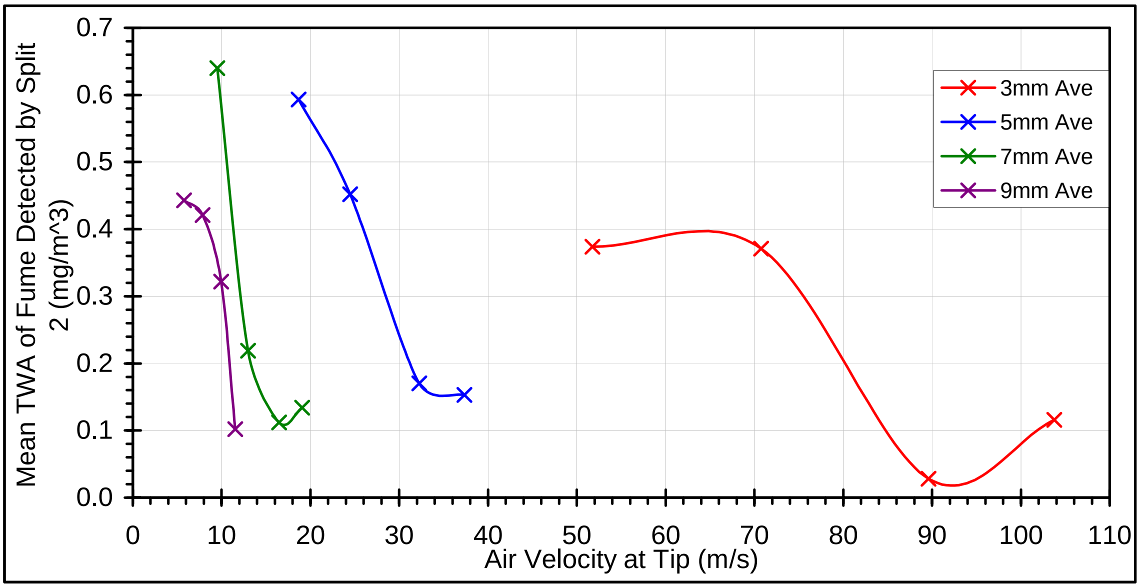

Figure 3.4: Mean TWA of Colophony Fume Detected as a Function of Air Flow Velocity at Each Extraction Tube Aperture Diameter

4 CONCLUSIONS

Over the range of parameters considered in this investigation (extraction tube apertures ranging from 3 mm to 9 mm diameter, extraction flow rates ranging from 22 l/min to 44 l/min) the following conclusions may be drawn:

1. The extraction flow rate is the most important aspect of a solder fume tip extraction system, and should therefore be the prime consideration when improvements to existing systems are required.
2. Increasing the extraction flow rate shows a measurable, but evidently non-linear increase in extraction effectiveness.
3. Changes in aperture size or air flow velocity have negligible effect on extraction effectiveness unless they result in changes in extraction flow rate.

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