

# Fumes produced during brazing with silver brazing alloys

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# Environmental monitoring: 9

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## Fumes produced during **BRAZING**

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Having covered more general matters in earlier articles in this series *HS* is now dealing with specific substances. After silica, lead and asbestos, **Laurie Heathcote** of Johnson Matthey Metals Limited examines the problems associated with fumes produced during brazing site silver metal alloys.

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The majority of metal articles produced these days are assembled from two or more parts held together with mechanical fasteners such as screws, clips or rivets, or by a thermal joining process. The family of thermal metal joining processes can be roughly divided into two — welding, and brazing and soldering.

*Welding:* Welding is the joining of two pieces of metal using a thermal process such that the final joint has similar properties or composition to the parent materials. Melting of the parent metal can take place together with diffusion. Filler metal may be added and pressure may be applied.

*Brazing and soldering:* This process is defined as a means of joining two materials by heating them to a suitable temperature and by using a filler metal having a melting temperature lower than either of the parent materials. The filler metal is distributed between the closely fitting surfaces of the joint by capillary attraction.

Where the melting temperature of the filler metal is lower than 450°C the process is called soldering. Where the melting temperature of the filler is above 450°C then the operation is called brazing.

Brazing itself is sub-divided into low temperature brazing, generally accepted as being up to 1000°C, and high temperature brazing, often using precious metals and nickel, where the temperatures are in excess of 1000°C.

Soldering and brazing are not modern processes and a study of the royal Sumerian tombs, some 4-5000 years old, has shown that complex objects were often cast in several moulds and the pieces joined together. Analyses of some of the weapons and ornaments has revealed that the smiths had been experimenting with soldering and brazing.

We are all familiar with the soft solders used in the production of electronic circuit boards and car radiators which are basically alloys of lead and tin, with melting points between 130-300°C. When greater mechanical strength is required or where the joints may be subject to higher temperatures then brazing will be the preferred process.

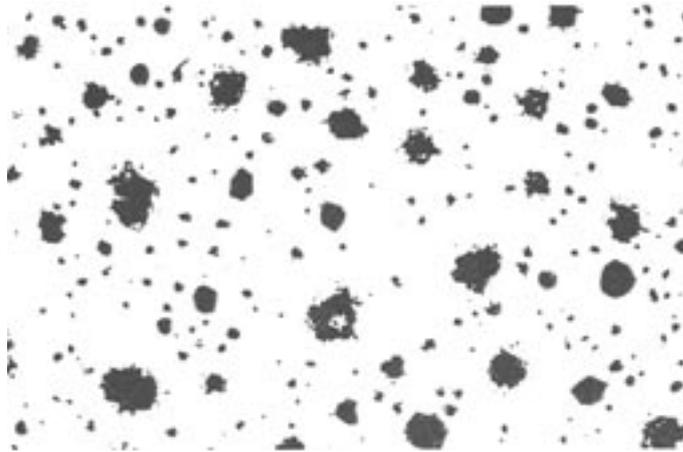
For most practical brazing applications low temperature silver brazing, sometimes called hard soldering, is the most economical process due to the low melting temperatures and good flow characteristics of the alloys. These characteristics are achieved by adding zinc, cadmium or tin to the basic silver and copper alloys. This combination has produced a range of silver brazing alloys listed in British Standards 1845 and the Continental DIN Standards (Table 1).

For satisfactory brazing operations it is necessary for the parent metal to be clean so that it can be wetted by the brazing alloy. The oxidation of metal surfaces during brazing can be prevented by the

use of a protective atmosphere or a vacuum, but the more common technique for low temperature silver brazing alloys is to use a flux. The function of a flux is to dissolve the metal oxide but at the same time remain fluid so that it can be displaced from the joint area by the molten brazing alloy. The usual commercial fluxes for silver brazing are mixtures of potassium fluoride, borates and/or their complex salts. These are supplied either as a fine powder or as a water based paste. The fluid and active temperature range of a flux must match the melting range of the filler metals to be used. For silver brazing alloys this is 550 to 800°C. Higher temperature fluxes will be similar in properties but have different compositions.

Silver brazing finds many applications in the engineering industry for the production of domestic appliances, cars, electric motors and so on. Specialised alloys are also used in the plumbing industry. The versatility in performance and the flexibility of application of the process is one of the reasons for the extremely wide range of uses.

A single joint can be made with the use of a hand held torch in some remote part of a factory during maintenance work, or a small manufacturer can braze a few hundred assemblies per day with similar equipment. On the other hand large numbers of brazed assemblies can



*Fig 1 Transmission electron micrograph of brazing fume x6 250. The droplet like particles range in size between 0.3 and 3.0  $\mu\text{m}$ . Very small particles are about 4nm in diameter. X-ray spectra indicated K and Cd to be major constituents with Zn, Al, Si and Cl also present*

TABLE 1 Some Commonly Used Brazing Alloys Examined for Fume Emissions

BRAZING Alloy BS and DIN Spec.	Melting Range °C	Ag	Cu	Zn	Cd	Ni	Mn	In	Sn	P
1 BS1845, AG2	608-617	42%	17%	16%	25%					
2 --	612-668	34%	25%	20%	21%					
3 --	616-735	23%	35%	27%	15%					
4 BS1845, CP2	644-700	2%	91.5%		--					6.5%
5 BS1845, AG9	634-656	50%	15.5%	15.5%	16%	3%				
6 BS1845, AG13	625-705	49%	16%	23%	--	4.5%	7.5%			
DIN 8513 L-Ag49										
7 --	600-711	56%	27%	0.034%	--	2.5%		14.5%		
8 --	790-830	16%	50%	34%	--					
9 --	700-740	33%	33.5%	33.5%	--					
10 --	630-660	55%	21%	22%	--				2%	

*It is recommended that alloys 6-9 which are essentially cadmium-free should have a maximum impurity level of 0.025%. Neither BS nor DIN standards include this requirement at present*

be produced on automatic machines whilst other heating methods such as induction or furnace are widely employed. There are in fact very few factories where silver brazing is not used in some form.

Brazing is a process involving the handling of hot metal and the dangers associated with this and the heating processes are well documented. The brazing operation, however, can give rise to both gaseous and particulate emissions from the molten alloys, flux and flames, and it is these aspects which are the subjects of this article.

Hand held torch brazing can present more problems from exposure of the operator to fume than any of the automated or furnace processes. This is because the latter processes should be adequately ventilated although in general the torch brazer will be blowing fume away from his own breathing zone.

The average brazed joint will be made with the operator's face roughly 0.4 metres from the components being joined. Therefore if the components are on a bench the concentration of contaminants within a hemisphere of 0.4 metres radius is what should concern us. For a free standing structure the hemisphere becomes a sphere. However, this is a little idealistic, assuming perfect mixing of the fume in the hemisphere and ignoring thermal effects and the flame velocity. In addition to the immediate exposure of the operator there is the general contamination of the work room with brazing fumes which will affect other people not necessarily carrying out brazing operations.

#### **Fume emission from the brazing alloys**

The factors which affect the quantity of fume emitted during brazing operations are:

- The vapour pressures of the elements present at the temperatures reached.
- The melting range of the alloy.
- The concentration of a particular volatile component of the alloy.
- The surface area of molten alloy exposed to the atmosphere.
- The time for which the alloy is held molten.

The alloy composition and vapour pressures of the metals present are fundamental properties and cannot be altered by the user, but the surface area of molten metal, final temperature reached above the melting point and time for which the alloy is held molten are all variable.

The fume emissions described here have been determined by carrying out a series of brazing operations in a closed cabinet and sampling the atmosphere produced<sup>1</sup>. The results have shown quite clearly that when zinc and cadmium are major constituents of a brazing alloy it is these elements which form the greater part of the fume produced. This is only to be expected from the boiling points and vapour pressures shown in Table 2. When collected by electrostatic precipitation and examined under an electron microscope, the fume can be seen as droplet-like particles ranging in size between about 0.3 and 3µm (Figure 1). The largest particles appear to be clusters of much smaller particles, some of which are only 4 nm in diameter. The elements shown to be present by the X-ray spectra include potassium, cadmium and zinc, of which cadmium and potassium are probably the major constituents with cadmium bearing alloys. These particles are, therefore, well within the respirable range. It has always been assumed that the particles are the oxides of the metals cadmium and zinc for which threshold limit values have been assigned by the American Conference of Governmental Industrial Hygienists<sup>2</sup> and adopted by the HSE (Table 3). However, the presence of flux material (potassium) associated with the fume complicates the issue, and characterisation of the particles is currently under investigation.

Cadmium is by far the most toxic of the metals present and this aspect was reviewed in *HS* in January 1980. Copper fume emitted from the brazing alloy is low, but when a large area of copper has been heated during brazing an aerosol containing copper has been detected in an operator's breathing zone. This may be copper fume, for which the TLV is 0.2 mg/m<sup>3</sup> or perhaps copper oxide dust cracked from the surface of the copper parts being joined, for which the TLV is 1.0 mg/m<sup>3</sup>.

The concentration of the silver and other brazing alloy constituents

(Table 2) in the fume were found to be low enough to be discounted as possible health hazards under normal circumstances. The zinc and cadmium concentration in the fume were therefore examined against the following brazing conditions:

- 1 The temperature to which the alloy was raised above its melting point.
- 2 The time taken to complete the joint, and therefore the time for which the alloy was held molten.
- 3 Heating the alloy directly with a torch flame instead of heating the joint and then applying the alloy to the hot metal (indirect heating). Direct heating will produce high surface temperatures.
- 4 The exposure of a large surface area of molten alloy to the atmosphere.

Conditions 1 and 2 are interdependent since the longer you heat the joint after the brazing alloy has melted then the hotter it will get. Conditions 1 to 3 are, therefore, under the control of the brazer to a large extent, although joint design may play some part.

The fume emissions shown here have been translated into a form which may be more appreciated than a table of quantities per unit mass of alloy. The hemisphere or fume envelope which has already been mentioned is used to illustrate the possible cadmium and zinc concentrations in a worker's breathing zone (Figure 2). An alloy containing cadmium as an impurity of 0.025 per cent may still give rise to some cadmium fume but the levels in a worker's breathing zone should be below the TLV of 0.05 mg/m<sup>3</sup>. The increase in zinc oxide emissions from this "cadmium free" alloy are due to a combination of increased zinc content and higher melting range. It must be said that in practice the concentration detected within the breathing zone of an operator when using a 25 per cent Cd alloy has been around the TLV of 0.05 mg/m<sup>3</sup> and not as high as that suggested in theory. This is because the distortion of the hemisphere by the heat and velocity of the torch flame tends to carry the fume up and away from the brazer. The duration of exposure will of course depend upon the frequency with which the operation is carried out as well as the time for which the alloy is held molten.

The second consideration must be the contamination of the workshop atmosphere where regular brazing operations are being carried out. To illustrate this point the ventilation requirements have been calculated in air changes per hour needed to keep the cadmium concentration at less than half the TLV ie 0.025 mg/m<sup>3</sup> for a workshop with a volume of 100 cubic metres housing five operators using a total of 300 g of brazing alloy per hour. The results obtained are used in Table 4 to show the effects of different brazing conditions and alloy composition. Zinc oxide emissions are very much lower and the ventilation requirements

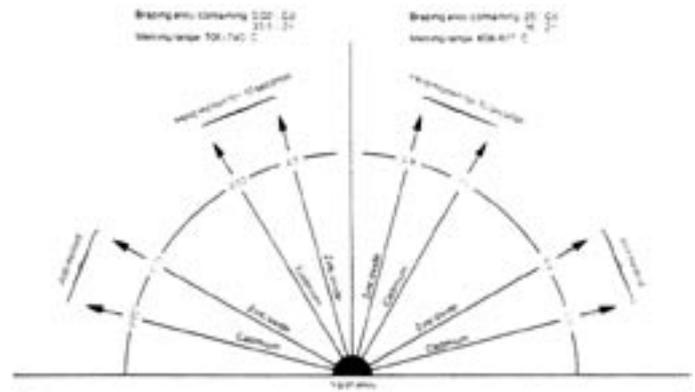


Fig 2 Cadmium and zinc oxide release into a hemisphere of 0.4m radius when 1g of a brazing alloy is melted at the centre and there is perfect mixing of the fume. The concentrations are shown in mg/l and a worker's breathing zone is assumed to be at the edge of the hemisphere when bench brazing

to keep these levels below half the TLV (ie <2.5 mg/m<sup>3</sup>) range from 0.02 to 2.0 air changes per hour for the same conditions.

HSE Guidance Note EH22<sup>3</sup> makes recommendations for fresh air requirements for different applications including board rooms, kitchens, shops and factories, and quotes cubic feet of fresh air per minute per person over the range of 7.5 to 50. For factories where there is no smoking the figure recommended is 0.283 cubic metres per person per minute. For five workers the fresh air requirements are 85 cubic metres per hour, which is less than one air change per hour in a 100 cubic metre workroom. By increasing the ventilation rate to three air changes per hour for this workroom, which is not unreasonable, a "cadmium-free" brazing alloy (ie an alloy where the cadmium content is less than 0.025 per cent) can be used without local exhaust ventilation or having to resort to a booth. Therefore, there is an obvious advantage in the use of cadmium free alloys where the engineering requirements can be met.

The most noticeable effect of surface area on fume emission can be seen when the brazing alloy, in sheet form, is placed between the components to be joined before heating and there is only a very thin edge exposed to the atmosphere. This situation might arise when resistance brazing contacts and cadmium fume emissions are negligible even with a high cadmium bearing alloy such as No 1, Table 1.

Alloys of silver, copper and phosphorus are self-fluxing when used on copper articles. The phosphorus is present as copper phosphide and

TABLE 2 Physical Properties of Elements found in Silver Brazing Alloys. Vapour Pressures Were Calculated from published formulae.

Element	Melting Point	Boiling Point	Vapour Pressure in mmHg			
			600°C	700°C	800°C	900°C
Silver	962°C	2212°C	1x10 <sup>-7</sup>	1.72 x 10 <sup>-6</sup>	4.29 x 10 <sup>-5</sup>	6.17 x 10 <sup>-4</sup>
Copper	1083°C	2567°C	--	2.11 x 10 <sup>-9</sup>	9.6 x 10 <sup>-8</sup>	2.29 x 10 <sup>-6</sup>
Zinc	420°C	907°C	11	60	232	703
Cadmium	321°C	765°C	36	342	760	--
Nickel	1453°C	2732°C				1,000°C 1.2 x 10 <sup>-6</sup>
Manganese	1244°C	1962°C	0.9 x 10 <sup>-7</sup>	0.88 x 10 <sup>-6</sup>	1.15 x 10 <sup>-4</sup>	1.4 x 10 <sup>-3</sup>
Indium	1570°C	2080°C	4 x 10 <sup>-4</sup>	5 x 10 <sup>-3</sup>	5.7 x 10 <sup>-2</sup>	0.73
Tin	232°C	2260°C	--	7.4 x 10 <sup>-6</sup>	8.5 x 10 <sup>-5</sup>	3.8 x 10 <sup>-4</sup>

TABLE 3 Threshold Limit Values of substances found in brazing alloys and those which may be detected in the fume produced during brazing operations HSE Guidance Note EH 15:80

	TLV - TWA (Time Weighted Average) mg/m <sup>3</sup>	TLV - STEL (Short Term Exposure Limit) mg/m <sup>3</sup>
* Silver, soluble compounds as Ag	0.01	0.03
* Silver, metal	0.1	--
Copper as fume	0.2	--
Copper as dust and mists	1	2
Cadmium oxide fume (as Cd)	0.05	(ceiling value not to be exceeded)
Zinc oxide fume	5	10
Nickel metal	1	--
Manganese fume (as Mn)	1	3
Indium and compounds (as In)	0.1	0.3
* Tin oxide (as Sn)	10 (2)	20 (4)
Fluoride (as F)	2.5	--
Phosphoric Acid	1	3
Hydrogen fluoride (as F)	2.5 (3 ppm)	5 (6 ppm)
Boron trifluoride	3 (1 ppm)	(ceiling value not to be exceeded)
Carbon Monoxide	55 (50 ppm)	440 (400 ppm)
* Nitrogen dioxide	6 (3 ppm)	10 (5 ppm)

\* Proposed intended change of TLV

the possible fume emission would be phosphorus pentoxide (P<sub>2</sub>O<sub>5</sub>). This can react with moisture giving phosphoric acid (H<sub>3</sub>PO<sub>4</sub>). In practice it has been found that the concentration in a worker's breathing zone is of the order of 0.05-0.1 mg/m<sup>3</sup> compared with the TLV of 1 mg/m<sup>3</sup>.

### Flux fumes

The fluxes used for silver brazing are based upon the metal alkali borates and fluoroborates and are generally applied to a joint as a water based paste before heating. The flux will melt before the brazing alloy and must remain in contact with the work for the cleaning action and metal to metal bonding to take place. As the heating process starts the flux paste will bubble and spit, so that particulates are discharged into the atmosphere. The large particles will quickly settle out and a ring of dried flux can sometimes be seen on the bench. The finer particles will remain airborne as a spray which will dry out to produce a solid aerosol. Once the flux is dry it will eventually form a viscous melt as heating is continued. Bubbling may continue at this stage producing more fine particulates. Finally as the brazing alloy melts and flows under the flux layer further bubbling can be seen to take place. The cause of this late stage bubbling is not very clear and the gases produced have not been identified, but the process is under investigation.

There are possibly two gaseous decomposition products during the heating of these fluxes, namely, hydrogen fluoride (HF) and boron trifluoride (BF<sub>3</sub>). Neither of these gases are easy to quantify in the presence of the other emission products. However an investigation is being carried out under laboratory controlled conditions and the results so far suggest that HF and BF<sub>3</sub> concentrations in an operator's breathing zone are likely to be below the TLVs (Table 3). This conclusion is based upon the hemispherical fume envelope concept.

Particulate emissions are easily collected along with the other fume components and are measured and recorded as fluoride ion for which the TLV is 2.5 mg/m<sup>3</sup>. The results are presented in Figure 3. The fluoride emission appears to be directly related to cadmium emission and hence to the concentration of cadmium in the alloy. Analysis of the fume particles seen on a transmission electron microscope (TEM) suggests that the particles may be composite ones containing both flux fragments and metal particles. These results show that a change from the use of a cadmium bearing to a cadmium-free alloy will generally reduce flux fume emission during the brazing process.

### Gases produced in the torch flame

There is a wide variety of gas mixtures which can be used for hand torch brazing, ranging from oxy-acetylene to compressed air/natural

gas, and thus providing a wide range of flame temperatures and heating rates. For the majority of applications the flame should be slightly on the reducing side to help prevent oxidation of the metal surfaces. Under reducing conditions combustion will be incomplete and some carbon monoxide will be formed. If an oxidising flame is used and there is an excess of oxygen, then oxides of nitrogen will be produced. The conditions to produce any of these compounds very much depend upon the work requirements and it is not possible to forecast concentrations for these gases.

### Sampling workshop atmospheres

The purpose of sampling a workshop atmosphere is twofold — to determine the degree of exposure of the workforce to toxic contaminants, and for an assessment of the efficiency of general and local extraction systems.

Sample collection in the breathing zone of a worker is the only satisfactory way of determining exposure to brazing fumes, and would also be used to determine the effectiveness of a local exhaust system. A background sample would be collected to determine the general level of atmospheric contamination in a workroom and hence the performance of general or local ventilation systems. The location of the breathing zone is not usually clearly defined and most samples are collected with the sampling head attached to the worker's overall lapel 0.2 to 0.3 metres from the nose and mouth. This is not entirely satisfactory for monitoring brazing fumes where the nose and mouth may be nearer the source of emission than the lapel. The UK draft standard for the collection of welding fume<sup>4</sup> sites the sampling head to one side of the nose and mouth (25 mm from the cheek) mounted inside the helmet. There are some similarities in the processes of welding and brazing, but there is currently no standard for the sampling of brazing fume. A code of practice for the sampling and analysis of cadmium is due to be published by the HSE and September 1981 was the target date. Siting the sampling head in the position for welding fume collection could be achieved by using a welding headshield frame, minus the shield, with an arm positioned to hold the filter 25 mm from the worker's cheek.

However, wherever the sampling head is located, the fume is collected on a filter which may be a cellulose ester membrane type with a pore size of 0.8 µm, or glass fibre such as a Whatman GF/A. Both have their advantages and disadvantages, but the membrane filters are generally recommended for chemical analysis.

### Cadmium

The TLV for cadmium is a ceiling value which means 0.05 mg/m<sup>3</sup>

must not be exceeded even for an instant. But a finite time is needed to collect enough fume particulate on the filter for analysis.

In the USA, NIOSH<sup>5</sup> recommend a 15 minute sampling period for ceiling levels collected over the time of expected maximum emission, but no sample size is defined in the UK. It is generally thought that ten minutes will be the sampling time recommended in the HSE code of practice yet to be published. At an air sampling rate of 2 litres per minute this will give a total volume of 20 litres and at the TLV the mass of cadmium collected on the filter would be 0.001 mg. Background sampling can be carried out over longer periods than ten minutes in order to determine the effectiveness of the workshop ventilation system.

The collected fume is dissolved by leaching the filter for 10 minutes with 5 mls of cold 50 per cent nitric acid. The resulting solution is analysed using an atomic absorption spectrophotometer (AA), which should be capable of detecting 0.0002 mg of cadmium. Therefore, with a ten minute sampling period concentrations down to one fifth of the TLV can be detected.

A portable AA for the direct measurement of cadmium in the atmosphere has been described by White<sup>6</sup> and is currently marketed by the British Non Ferrous Metals Technology Centre. Butane gas is used to fire the self blowing burner which draws air from the surrounding atmosphere to be sampled. The meter reads directly in mg of cadmium per cubic metre of air.

#### *Silver, copper, zinc and the minor alloy constituents*

With the exception of tin oxide these metal fumes will be leached from the filter along with the cadmium, and so the same acid solution may be used for AA analysis for these elements. Tin oxide is insoluble in nitric acid and cannot be determined by this method, but since the TLV is high, 10 mg/m<sup>3</sup> for SnO<sub>2</sub>, and the vapour pressure is very low at brazing temperatures it is most unlikely to be found in the fume in hazardous quantities. (NB There is notice of an intended change of TLV with

tin from the one given here down to 2 mg/m<sup>3</sup> in the 1980 list in HSE Guidance Note EH15/80).

#### *Fluoride particulates*

A separate filter sample is needed for fluoride ion analysis, or a single filter can be divided for both metal and fluoride analysis. The analytical method is described in the British Standards Institution draft for development for analysis of welding fume<sup>4</sup>. The filter is leached for ten minutes with 2 mls of warm 1:1 HCl and the solution decanted and made up to 25 mls in a volumetric flask containing 5 mls of a sodium acetate/1,2 diaminocyclohexane NNN tetra-acetic acid buffer solution. Standards are prepared from a sodium fluoride solution in a similar manner. The total fluoride is then determined from emf measurements obtained using an ion specific electrode and a pH meter capable of reading 1 mV or less. By reference to a prepared calibration graph the mass of fluoride contained on the filter can be found.

#### *Gaseous hydrogen fluoride and boron trifluoride*

These gases may be collected in dilute sodium hydroxide solution in a bubbler, but a filter must be placed in the sample line to remove the fluoride particulate first. The fluoride and boron trifluoride ions can then be estimated using the appropriate ion specific electrodes and a pH meter. The apparatus used for gas collection must be of polypropylene or PTFE and not glass because of its interaction with HF.

#### *Carbon monoxide and oxides of nitrogen*

Detector tubes are available for both long and short term sampling of CO and NO<sub>x</sub>. The HSE booklets<sup>7</sup> on the detection of toxic substances in air include colorimetric methods for CO and nitrous fumes which are described as a mixture of nitrogen dioxide (NO<sub>2</sub>) and dinitrogen tetroxide (N<sub>2</sub>O<sub>4</sub>). There are instrumental methods for both these gases and include chemi-luminescence for NO/NO<sub>2</sub>, electrochemical for NO/NO<sub>2</sub> and CO, and infra-red spectrometry for CO.

TABLE 4 Ventilation requirements for a workroom of 100m<sup>3</sup> volume housing 5 operators using a total of 300g of brazing alloy per hour. Airborne cadmium levels to be kept below half the TLV, i.e. <0.025 mg/m<sup>3</sup>. The temperature of the alloy reached at each stage of the test is shown in brackets.

Alloy No.	Cadmium Content of Alloy	Number of Air Changes Per Hour		
		Just Melted	Held Molten for 10 seconds	Held Molten for 30 seconds
<b>Direct Flame Heating</b>				
1	25	30 (617°C)	420 (730°C)	972 (815°C)
2	21	108 (668°C)	372 (760°C)	--
3	15	48 (735°C)	1020 (780°C)	--
5	16	48 (656°C)	204 (750°C)	468 (820°C)
8	0.02	2.4 (830°C)	2.4 (840°C)	5.4 (840°C)
9	0.0037	0.37 (740°C)	0.48 (835°C)	0.6 (840°C)
10	0.03	0.72 (640°C)	1.44 (825°C)	1.44 (840°C)
<b>Indirect Flame Heating</b>				
1	25	34 (617°C)	120 (685°C)	--
2	21	36 (668°C)	132 (710°C)	--
3	15	36 (735°C)	36 (755°C)	--
5	16	16 (656°C)	16 (705°C)	--
8	0.02	1.0 (830°C)	2.4 (930°C)	3.6 (930°C)
9	0.0037	0.2 (740°C)	0.4 (930°C)	0.7 (930°C)
10	0.03	0.2 (640°C)	0.4 (930°C)	1.0 (930°C)

## General workshop hygiene

The subject of this article is brazing fume emissions but a general word about workshop hygiene will not be amiss.

When cadmium bearing alloys are used there will be a certain degree of contamination of work benches, fire bricks, and furnace linings used in the brazing operations. Furnaces which have been used for brazing and at the time were correctly coupled to fume extraction equipment may, at some time later, be used for work which does not require such stringent ventilation requirements, and cadmium could be released from the furnace lining to contaminate the workshop atmosphere.

Smokers have a bad habit of putting a lighted cigarette on the edge of a table or bench and in this way cadmium bearing dust may be picked up on the cigarette and be subsequently transferred to the mouth or inhaled with the tobacco smoke.

Silver brazing fluxes which contain alkali metal borates and fluoroborates have proved to be moderately irritating to the skin and contact with abraded skin should be avoided. The suppliers should always be consulted with regards to the hazards associated with the handling of their fluxes and indeed the brazing alloy which is in use. In this connection it is pertinent to note that reputable suppliers already make available hazard data sheets to conform with their duties under section 6 of the HSWA 1974.

## Ventilation

Brazing operations with alloys containing cadmium as a major constituent should only be carried out under well ventilated conditions whether done in air or in a furnace. When brazing is to be carried out on a bench then a booth with extraction should be used. A booth for hand torch brazing has been developed by the British Association for Brazing and Soldering at the British Non Ferrous Metals Technology Centre. The booth is described in detail in a BABS publication on the safe use of cadmium containing filler metals<sup>8</sup>.

A simple local exhaust extraction system such as that used for welding would require careful design and positioning to capture all the fume produced because gas/air mixtures have high flame speeds. If the collector is placed too close to the work then the high capture velocities needed will disturb the torch flame, but this kind of system can be used for inducting brazing. For flame brazing a local exhaust system will remove only part of the fume generated but it would be better than no extraction at all.

Where brazing is carried out in a confined space then a suitable fume filter face mask should be used providing there is no question of depletion of oxygen in the atmosphere. Under these circumstances a helmet fed with fresh air or self contained breathing apparatus is to be preferred. Care must be taken to ensure that factory regulations for working in confined spaces are adhered to. (The use of personal respiratory protection is only to be considered where the nature of the process makes the use of exhaust appliances impracticable within the terms set down in section 63 of the Factories Act 1961.)

## Conclusions

Cadmium is the only element present in the silver brazing alloys, considered in this article, which is likely to be emitted in sufficient quantity to contravene the present hygiene standards. Most of the figures for quantities of fume emitted were obtained under laboratory conditions, but the few field trials carried out on a bench show that they do relate to real situations. If anything, the estimated breathing zone levels at the edge of the hemispherical envelope (Figures 2 and 3) are on the high side.

There have been a few cases of acute toxic effects when brazing with cadmium bearing alloys, but in general it is the chronic effects which may be experienced by brazing operators. However any results obtained in a laboratory can only be taken as guidelines, and each brazing operation must be judged separately taking into consideration such facts as: -

- The composition of the brazing alloy.
- The volume of the workroom.
- The number of operators.
- The siting of the brazing benches in the workroom.
- The rate of consumption of the alloy.

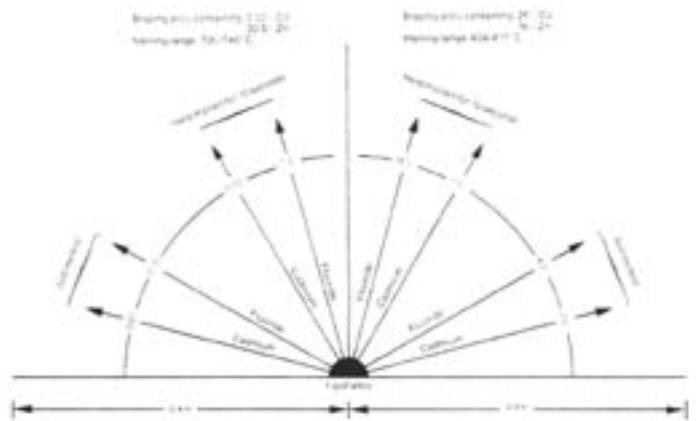


Fig 3 Cadmium and fluoride particulate release into a hemisphere of 0.4m radius when 1g of a brazing alloy is melted at the centre and there is perfect mixing of the fume. The concentrations are in mg/m<sup>3</sup> and a worker's breathing zone is assumed to be at the edge of the hemisphere when bench brazing

- The weight of alloy and the exposed surface area.
- The ventilation and airflow patterns around the working area. Personal monitoring of the workforce should always be carried out where there is any doubt about the adequacy of the ventilation system. Brazing alloys which contain small amounts of cadmium as impurity emit far less cadmium fume during use and are to be recommended for hand torch brazing where the engineering requirements are satisfied. Even with cadmium-free brazing alloys, where there can be some residual cadmium fume, a workroom ventilation rate is required which is somewhat better than the minimum recommended in HSE Guidance Note EH22.<sup>3</sup> It should be noted that from experimental evidence it is necessary to have a cadmium concentration less than 0.025 per cent to ensure that the TLV of 0.05 mg/m<sup>3</sup> will not be exceeded. Under these conditions a brazing booth should not be necessary provided there is a good circulation of fresh air.

Bad brazing practices will result in higher fume emissions than necessary and the following "don'ts" should be respected:

- Don't heat the alloy directly with the torch flame.
- Don't hold the alloy molten for longer than is necessary to complete the joint.
- Don't heat the alloy to a temperature excessively above its liquidus.
- Don't have large areas of molten alloy exposed to the air.

Particulate fluoride emissions seem to be related to the cadmium emissions, and will therefore be reduced with cadmium free alloys. However, both these and the gaseous products of silver brazing fluxes are still under examination. Whatever precautions are taken during the use of brazing alloys with regards to cadmium should be adequate for fluoride particulate and gaseous emissions.

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