

Bronchial provocation studies in workers exposed to the fumes of electronic soldering fluxes

P. S. BURGE, M. G. HARRIES, I. O'BRIEN and J. PEPYS

Department of Clinical Immunology, Cardiothoracic Institute, Brompton Hospital, London

(Received 3 May 1979; accepted for publication 3 May 1979)

Summary

Flux cored solder commonly used in the electronics industry is a metal alloy, based on tin and lead, and a flux consisting of colophony with a small concentration of an activator. Thirty-four electronics workers with occupational asthma and seventeen with respiratory symptoms, probably from other causes, have been investigated by occupational type bronchial provocation testing. All the sensitized workers had a significant fall in FEV₁ after exposure to colophony fumes for 15 min or less. The non-sensitized workers had no significant reactivity to this test. There was little correlation between the reaction to colophony fumes and the non specific reactivity to histamine, suggesting that colophony fumes were causing specific sensitization. In sensitized workers Portuguese Y colophony was found to cause slightly larger reactions than similar exposures to American WW colophony. In the six workers tested reactions followed exposure to abietic acid alone, the principal resin acid in colophony. Methylation of the carboxyl group of colophony was associated with decreased reactivity.

Workers with non-specific bronchial hyperreactivity also sometimes reacted after exposure to fumes from the flux activators alone, but even this reaction could show specificity for the specific activator to which the worker was exposed. Finally two non-colophony substitute materials were evaluated.

Introduction

Occupational asthma can be a considerable problem in the electronics industry, affecting 22% of workers in one factory (Burge *et al.*, 1979a). The fumes evolved from the soldering fluxes appear to be the main sensitizing agents (Fawcett, Newman Taylor & Pepys, 1976; Burge *et al.*, 1978). Some factories also solder polyurethane coated wires, liberating fumes of toluene di-isocyanate (TDI). TDI fumes were responsible for an outbreak of occupational asthma affecting forty workers in one factory (Paisley, 1969) and have caused other sporadic cases (Pepys *et al.*, 1972). Other factories

Correspondence: Dr P. Sherwood Burge, Department of Clinical Immunology, Cardiothoracic Institute, Brompton Hospital, London SW3 6HP.

encapsulate their circuits in polyurethane or epoxy resin coatings, both capable of causing occupational asthma. There is a particular hazard when faulty encapsulated components are removed by burning through the coating.

Soldering fluxes are needed to stop oxidation of the heated metals at the solder joint, and to assist the melting and spreading of the solder. Non corrosive soft soldering fluxes, as used in the electronics industry, have been based on colophony (rosin, pine resin) since modern electronics began (Rubin & Allen, 1972). Fluxes used in mass production soldering techniques must act rapidly. For this activators are added in small amounts (usually 2–4% of the flux). These activators vary with the manufacturer. The activators used in this study are a high molecular weight aliphatic tertiary amine hydrochloride in Multicore 366 and 362 fluxes (subsequently called amine hydrochloride) and a mixture of amine hydrobromides in EGM superspeed fluxes (subsequently called amine hydrobromide). The two amines were different.

Hand soldering is usually carried out with flux cored solder. The flux runs in longitudinal cores within the metallic soldering alloy. Mechanical soldering separates the flux from the solder. The flux is in a liquid form, usually dissolved in isopropanol. The piece to be soldered is passed through a bath of the dissolved flux. The isopropanol is then evaporated before passing the piece through the molten alloy for soldering.

Colophony (rosin) is a product of pine tree resin. Gum rosin is produced by scarifying pine trees and collecting the crude oleoresin. This is washed to remove soluble acids and distilled under vacuum. The distillate is turpentine, the residue colophony. Colophony can also be produced from dead pine tree stumps (wood rosin) or the tall oil left over after Kraft pulp manufacture (tall oil rosin). The composition and purity of the colophony depends on the method of preparation (Lawrence, 1959; Enos, Harris & Hendrick, 1968). Colophony produced from tall oil is likely to be oxidized in the heating process decreasing the optical grade (Lawrence, 1959).

Colophony is a mixture of resin acids each containing one carboxyl group and either two (abietic type) or one (pimaric type) unsaturated double bonds (Fig. 1) with a neutral fraction. Colophonies from different species of pine trees differ in their ratio of abietic to pimaric type resin acids (Enos *et al.*, 1968), and also in the composition of the neutral fraction.

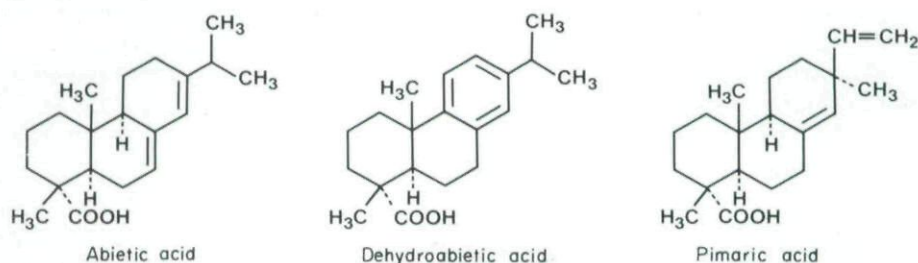


Fig. 1. Structure of the principal groups of resin acids in colophony.

Colophony in its solid state is a potent source of contact dermatitis, responsible for the common sticking plaster rash. Workers in the electronics industry are usually exposed to the fumes resulting from heating colophony at 350–450°C. The exact composition of the resulting fume is uncertain. Resin acids have been detected in the fume when heating to 300 but not 200°C (W. W. Melvin, E. B. Gray & A. R. Frazier, 1968, unpublished). The fume also contains higher carboxylic acids, aldehydes and carboxylic acids of lower molecular weight (Drugov & Murav'eva, 1976).

This study set out to investigate the cause of respiratory symptoms in a group of fifty-one electronics factory workers referred to the Brompton Hospital. All had bronchial provocation testing to the fumes of colophony and/or flux-cored solder. In the course of these investigations some workers were exposed to colophonies from different sources, and to chemically modified colophonies, to see if structural changes in the resin acids could modify their allergenicity. Some workers have also been exposed to the flux activators alone, and to non-colophony substitutes for use in soldering fluxes and hot melt glues.

Materials and methods

Fifty-one workers referred to the Brompton Hospital were studied. They came from sixteen separate factories, eleven of which were making consumer electronics by mass production techniques. The remaining five were making electronic equipment by hand. All workers were investigated as in-patients as previously described (Burge *et al.*, 1978). Only one provocation test was carried out on each day, FEV₁ and FVC were then monitored for the next 24 hr. If the test was negative it was repeated with a longer exposure the next day. A reaction was considered positive if the FEV₁ fell by 15% or more compared with a control day. Heated solder alloy without flux was initially used as a control, but latterly a hot melt glue without colophony (Monatex) or a flux cored solder without colophony (Zerodor, Multicore Ltd) were used for control exposures.

Exposures were made in a small cubicle with gentle air extraction. Fumes were produced by the worker touching the test material with a soldering iron at 350°C. This was repeated every 30 sec for a maximum of 60 min with flux cored solder, 15 min with colophony alone or 5 min with the activators alone. For workers with a history of moderate or severe reactions at work the first exposure was to one breath of fume with a maximum of 1 min exposure on the first test day. Workers with less severe reactions after exposure to fumes at work were started latterly with a 1 or 5 min exposure to the fumes from flux cored solder (day 2 or 3 on the original protocol, Burge *et al.*, 1978).

The challenge testing was standardized for the last ten subjects, when measurements of atmospheric colophony were made from breathing zone samples taken during the challenge testing. 16 s.w.g. flux cored solder was used with a soldering iron at 350°C. The solder was touched every 30 sec, such that 25 cm of solder was consumed evenly per 15 min of exposure. This resulted in mean atmospheric colophony levels of 0.54 mg/m³ for a 5 min exposure, 1.35 mg/m³ for a 15 min exposure and 1.54 mg/m³ for a 30 min exposure.

After a positive reaction had been elicited, some workers had comparative provocation tests on subsequent days. The exposure details were kept as similar as possible to the exposure producing a positive reaction. In this way comparisons were made between American WW colophony (Hercules Powder Co.), Portuguese Y colophony (Socer, Portugal) and abietic acid (Sigma Ltd.) and between Portuguese Y colophony and its methyl ester (Hercules Powder Co.) and its maleic modified glycerol ester (Hercules Powder Co.) (Fig. 2). Some workers were also exposed to fumes from flux activators, the amine hydrochloride in Multicore 366 and 362 fluxes and the amine hydrobromides in E.G.M. superspeed fluxes. Two workers were exposed to artist's grade turpentine by painting with the material for 30 min.

For each material a separate soldering bit and cellulose sponge was used to avoid cross contamination. When possible workers were studied when taking no drugs. However, corticosteroids were not withdrawn for the tests. If the FEV₁ was unstable

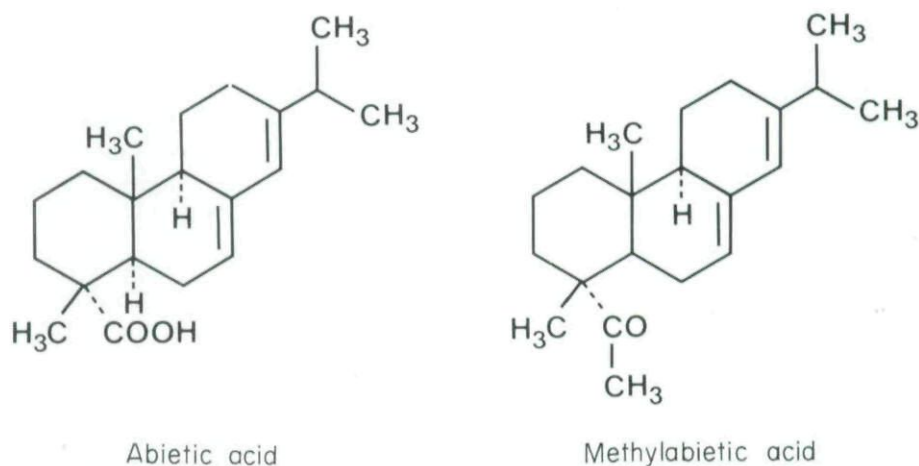


Fig. 2. Structures of abietic acid and its methyl derivative. The maleic modified glycerol ester has the methyl group replaced by glycerol; and the double bonds opened and linked to maleic acid anhydride.

without exposure between 9 a.m. and 10 p.m. then salbutamol (2 mg) was given by mouth every 2 hr from 6 a.m. to 10 p.m. This usually stabilized the FEV₁, after the early morning dip in FEV₁ had resolved and avoided the sharp swings in FEV₁ seen after inhaled salbutamol. Two workers had sufficiently variable values of FEV₁ throughout the day despite salbutamol to make the results of provocation testing equivocal. They have been omitted from the following results. Positive reactions were allowed to resolve spontaneously. Salbutamol (200 µg) was given by pressurized inhaler if the reaction was greater than expected; this was rarely necessary.

Bronchial reactivity to histamine was measured by a modification of the method of de Vries (O'Brien *et al.*, 1979). Exposures were for 30 sec. A reaction at 16 mg/ml or less signifies bronchial hyperreactivity, reactions at 32 mg/ml are borderline. Most normal people do not react at 32 mg/ml.

Results

Exposure to the fumes from flux cored solder for up to an hour or to the fumes from colophony for up to 15 min resulted in positive reactions in thirty-four workers, negative reactions in fifteen workers and equivocal reactions in two. The relationship between non specific bronchial hyperreactivity to histamine and the time of colophony fume exposure needed to produce a positive reaction is shown in Fig. 3 in the thirty-one of the thirty-four reactors who had both tests. The relationship was not significant for histamine reactivity of 32 mg/ml or less ($r=0.203$, Pearson's product moment correlation on log transformed data). However, there is a significant correlation when the histamine non-reactors are included in a ranking test ($r_s=0.42$, $P<0.025$, Spearman's rank test). This still 'accounts' for only 18% of the total variance. Fourteen of the fifteen workers with negative provocation tests were unreactive to histamine, the remaining one reacted at 8 mg/ml. Eighty-one per cent of the reactors did so at colophony exposure times of 5 min or less.

Fig. 4 shows the correlation between exposure times to flux cored solder and to colophony fumes in the twenty-two reactors who were exposed to both materials. The variance increases with exposure time, perhaps because the colophony exposure usually followed the flux cored solder, by which time some workers had become more

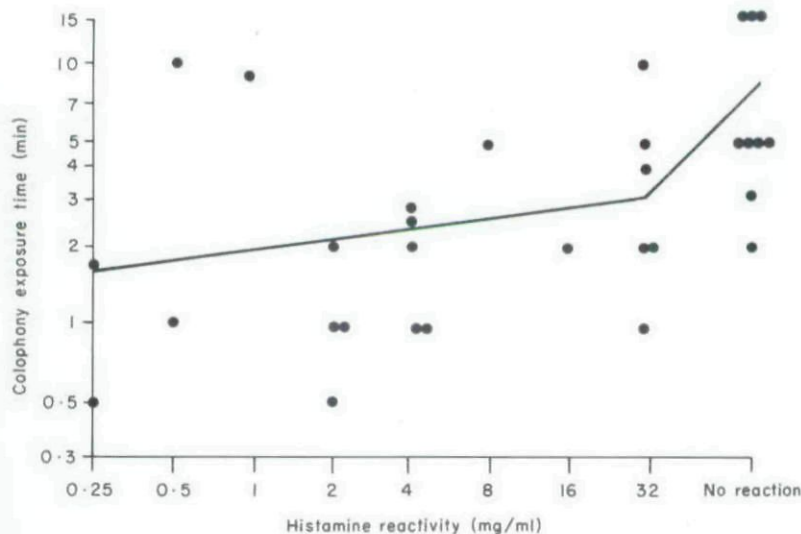


Fig. 3. Exposed electronics workers with positive provocation testing to colophony fumes. Relationship between non-specific bronchial reactivity to histamine and the duration of exposure to colophony fumes required to produce a reaction in the sensitized workers.

reactive ($r_p=0.533$; $P<0.02$, Pearsons product moment correlation on reciprocated data).

Comparison of Portuguese and American colophony

Twelve workers were exposed to the fumes from heated Portuguese Y and American WW colophony on separate days in random order. Exposure times were the same in six cases, were greater during exposure to American colophony in five and Portuguese in one case (Table 1). In nine workers the Portuguese colophony fumes resulted in the

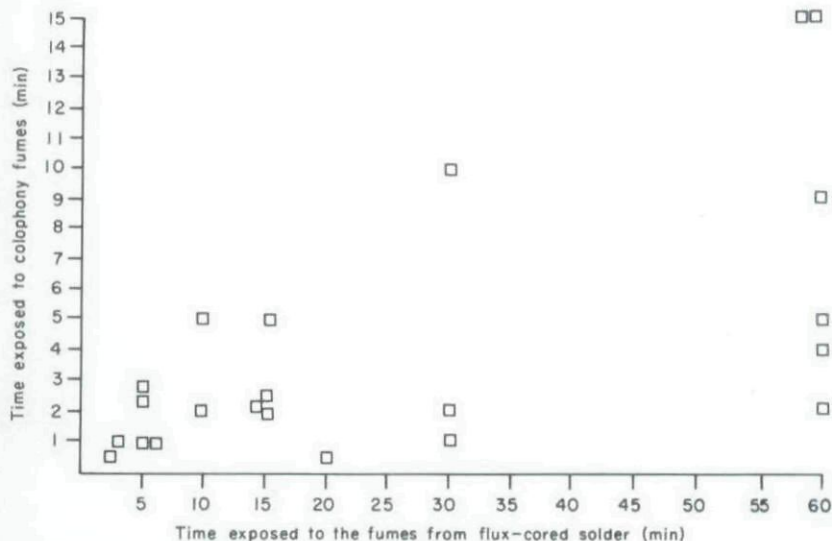


Fig. 4. Relationship between the exposure times required to produce a reaction after heating flux cored solder, and colophony alone.

Table 1. Comparison of immediate reactions after exposure to the fumes from American WW and Portuguese Y colophony in the same worker

	Portuguese colophony		American colophony		First challenge with Portuguese (P) American (A)
	Time of exposure	Max. % fall in FEV ₁	Time of exposure	Max. % fall in FEV ₁	
EB	3	35	5	11	A
MB	3	26	3	45	P
IB	4	27	8	6	P
JC	1	60	3	37	P
BG	3	35	3	15	P
JL	2.5	20	2.5	20	A
RP	1	41	1	33	P
CS	2	28	6	12	A
RS	5	17	15	10	A
CS	15	24	15	18	P
VS	5	22	5	15	P
MT	5	22	15	13	P

larger immediate fall in FEV₁ and in two the greater fall occurred on exposure to American colophony fumes ($0.1 > P > 0.05$, Wilcoxon signed rank test). The reactions were the same in one patient. The late asthmatic reactions were difficult to compare as many of the workers had insignificant late reactions.

Comparison of colophony and abietic acid

Six workers were exposed to the fumes of abietic acid, the principal acid of colophony. The results are shown in Table 2. Three of the six had larger reactions after abietic acid (first exposure to abietic acid in 2/3) and three larger reactions on exposure to colophony fumes (first exposure to abietic acid in 2/3). Figure 5 shows the results in one worker.

Reactions to the flux activators

Eighteen workers were exposed to the fumes from the amine hydrochloride, the

Table 2. Comparisons of immediate and late asthmatic reactions after exposure to the fumes from Portuguese colophony and abietic acid in the same workers

	Portuguese colophony (1)				Abietic acid (2)			
	Histamine reactivity (mg/ml)	Exposure time (min)	Max % fall in FEV ₁ (immediate)	Max % fall in FEV ₁ (late)	Exposure time (min)	Max % fall in FEV ₁ (immediate)	Max % fall in FEV ₁ (late)	Order of testing
DB	4	1	17	20	1	31	20	2, 1
JC	4	1	60	12	1	23	15	1, 2
MF	2	5	15	18	3	32	15	2, 1
JLa	4	3.5	20	19	4	28	13	1, 2
JLe	2	1	55	43	3	30	18	2, 1
IP	16	2	66	15	3	8	12	2, 1

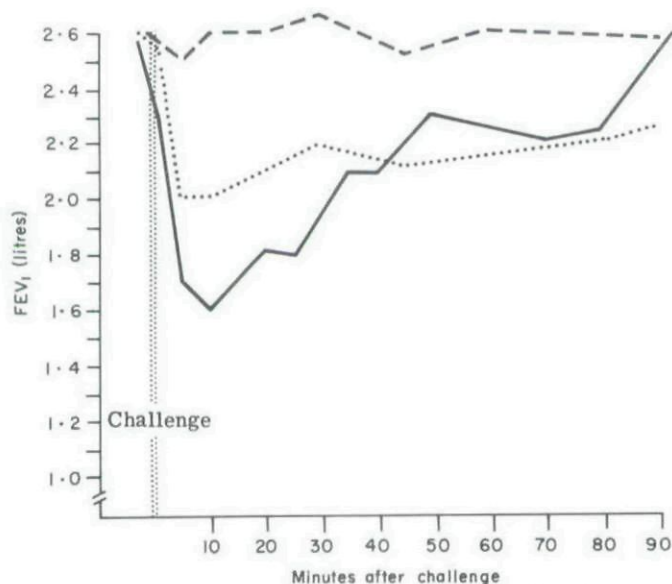


Fig. 5. Bronchial provocation test with exposure to the fumes from turpentine, American colophony and abietic acid (J.C.). —, American colophony (three breaths); ---, turpentine painted in 30 minutes; ···, abietic acid (ten breaths).

Table 3. Comparison of the immediate and late asthmatic reactions after exposure to the fumes from colophony and the amine hydrochloride in the same workers

	Histamine reactivity (mg/ml)	Exposure time (mins)	Colophony		Exposure time (min)	Amine HCl activator	
			Max. % fall in FEV ₁ (immediate)	Max. % fall in FEV ₁ (late)		Max. % fall in FEV ₁ (immediate)	Max. % fall in FEV ₁ (late)
EB	32	3	35	29	5	8	0
ABe	2	0.5	22	6	2	7	6
ABi	8	5	37	16	5	4	9
MB	32	5	23	22	3.5	8	0
IB	32	4	27	14	5	9	11
RC	No reaction	15	17	10	6	0	0
JC	4	1	60	12	1	15	0
RD	0.5	15	19	16	5	8	17
BG	4	3	35	18	5	6	33
JL	2	1	55	43	5	42	20
RP	0.5	1	41	41	1	29	52
IP	15	2	66	15	5	0	19
IR	32	15	6	15	5	0	0
CS	32	2	28	19	5	6	9
MS	1	9	14	10	5	7	14
LS	32	2	27	15	5	6	22
VS	No reaction	5	22	16	5	5	10
EV	0.25	10	68	39	5	19	3

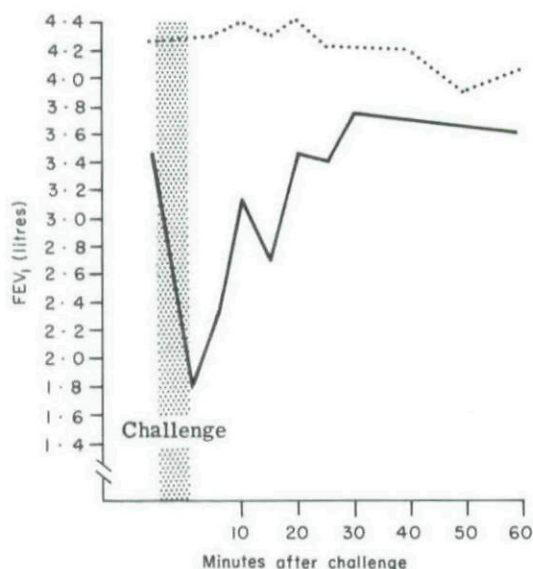


Fig. 6. Bronchial provocation test with exposure to the fumes from the amine hydrochloride flux activator, and to solder alone (J.C.). Solder without flux (30 min); —, Multicore flux activator (5 min).

Multicore flux activator for a maximum of 5 min. The fumes had a strong unpleasant smell which was not detectable in the fumes from heated flux cored solder. It is likely that the levels of fume achieved were considerably greater than that achieved in regular soldering. The results are shown in Table 3. Four workers had significant reactions to amine hydrochloride fumes, all had histamine reactivity at 4 mg/ml or less ($P=0.069$, Fisher exact test). Eight workers had a significant immediate or late asthmatic reaction

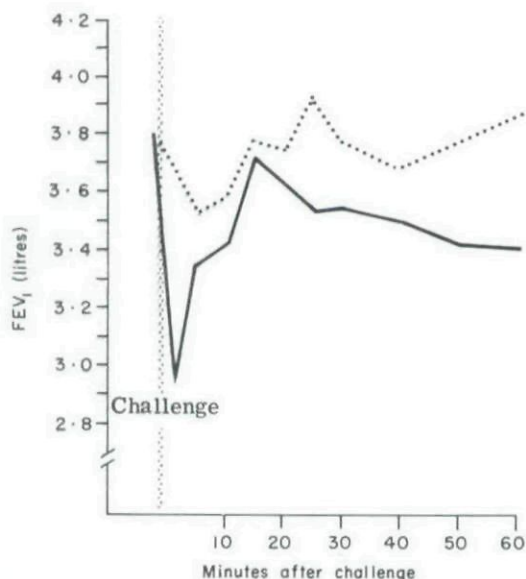


Fig. 7. Bronchial provocation test with exposure to the fumes from the amine hydrochloride (Multicore) and the amine hydrobromides (EGM) flux activators (A, B). Multicore activator (2 min); —, EGM activator (1 min).

Table 4. Comparison of the immediate asthmatic reactions after exposure of the fumes of Portuguese Y colophony—colophony methyl ester and maleic modified colophony ester in the same workers

	Histamine reactivity mg/ml	Portuguese colophony (1)		Colophony methyl ester (2)		Maleic modified colophony ester (3)		Order of testing
		Exposure time (min)	Max. % fall in FEV ₁	Exposure time (min)	Max. % fall in FEV ₁	Exposure time (min)	Max. % fall in FEV ₁	
JB	2	2	29	5	23	5	68	1, 2, 3
BG	4	3	10	3	11	3	17	1, 2, 3
DP	32	10	16	10	11	5	29	1, 3, 2
RP	0.5	1	41	1	16	1	52	1, 2, 3
MR	Not reactive	15	41	15	2	15	10	1, 3, 2
CS	Not reactive	15	24	15	0	15	5	1, 2, 3
VS	Not reactive	5	22	5	3	5	6	1, 2, 3
MT	Not reactive	5	22	5	8	5	5	1, 3, 2

to the amine hydrochloride. All but one had bronchial hyperreactivity to histamine ($P=0.023$, Fisher exact test). Figure 6 shows the results of provocation testing in one worker. All workers who reacted to the flux activators also reacted to colophony fumes alone. Four workers were additionally exposed to the fumes of the amine hydrobromide, the EGM flux activator. One had an immediate reaction and one a dual immediate and late asthmatic reaction. One worker had only been exposed to EGM solder at his work. He reacted to the EGM but not Multicore activator (Fig. 7). The other reactive worker was exposed to both solders at work. Three workers with negative provocation tests to colophony also had negative reactions to the flux activators.

Reactions to modified colophonies

Eight workers with positive reactions to colophony were exposed to the fumes of methyl ester of colophony and maleic modified glycerol ester of colophony on separate days (Table 4). Table 5 shows a summary of the results. Reactions were greatest to Portuguese colophony, slightly less to maleic modified glycerol ester of colophony and much less to methyl ester of colophony ($P\leq 0.05$, Kriskall Wallace H statistic). The

Table 5. Comparison of immediate asthmatic reaction after exposure to the fumes from Portuguese Y colophony, colophony methyl ester and maleic modified colophony ester in the same workers

	Portuguese colophony	Colophony methyl ester	Maleic modified colophony ester
Number tested	8	8	8
Largest reaction	5	0	3
Sum of percentage falls in FEV ₁	249	74	221

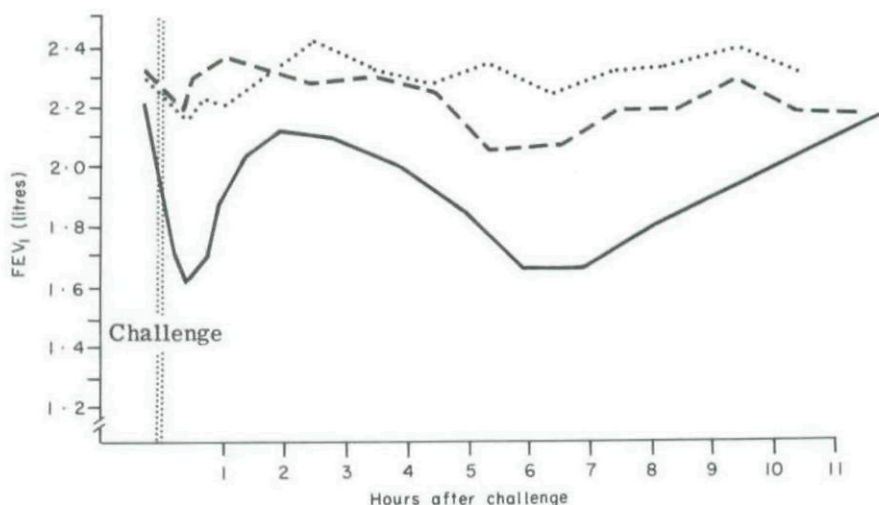


Fig. 8. Bronchial provocation tests with exposure to the fumes from Portuguese colophony, and its methyl ester and its maleic glycerol ester. ···, Colophony methyl ester (5 min); ---, maleic modified colophony ester (5 min); —, Portuguese colophony (5 min).

difference between the reactions to methyl ester of colophony and colophony is also significant ($P < 0.02$, Mann-Witney U test). Significant reactions to the maleic modified glycerol ester of colophony were confined to the four workers with bronchial hyper-reactivity. Figure 8 shows the results of one set of provocation tests.

The breathing zone concentration of fume obtained during a 5 min exposure to Portuguese WW colophony and its methyl ester was compared on five occasions using 1 g of ground colophony and 1 g of its methyl ester. The soldering iron at 350°C was dipped into the colophony for 5 sec every 60 sec. Results ranged from 0.03 to 0.20 mg/m^3 for Portuguese colophony and < 0.01 –0.44 mg/m^3 for methyl colophony.

Substitute materials in colophony sensitive workers

Monatex has been developed as a hot melt glue to replace colophony. Eight colophony sensitive workers were exposed to the fumes from this for at least as long as an exposure to colophony fumes. Two workers had 15% or more drop in FEV_1 after this. Both of these workers reacted to every material with which they were tested—their levels of histamine reactivity were at 0.5 and 8 mg/ml respectively.

Fifteen workers were tested with a substitute flux cored solder containing the same activator as Multicore 366 but no colophony (Zerodor). The results are shown in Table 6. Three workers had significant immediate and late asthmatic reaction after exposure for the same time or longer than a previous positive reaction to flux cored solder. Late asthmatic reactions alone occurred in four workers. Five reactors and five non-reactors to Zerodor were also tested with the flux activator alone; reactions to the flux activator alone occurred in 5/5 and 1/5 respectively ($P = 0.024$, Fisher exact test). However, six of the seven Zerodor reactors were reactive to histamine at 16 mg/ml or less compared with two of the eight non-reactors ($P = 0.0317$, Fisher exact test).

Discussion

This study has attempted to compare reactions following exposure to different consti-

Table 6. Comparison of the immediate and late asthmatic reactions to the fumes from a colophony-containing (Multicore 366) and colophony-free (Zerodor) flux cored solder in the same workers

	Reaction to amine HCl activator	Histamine reactivity (mg/ml)	Exposure time (min)	Multicore 366 with colophony (1)		Zerodor without colophony (2)		Order of testing
				Max. % fall in FEV ₁ (immediate)	Max. % fall in FEV ₁ (late)	Max. % fall in FEV ₁ (immediate)	Max. % fall in FEV ₁ (late)	
AB	Neg	2	2½	36	19	5	9	1, 2
MB	Neg	No reaction	10	18	14	10	5	1, 2
JL	Dual	2	6	60	17	6	5	1, 2
IP	Late	16	30	47	22	30	26	1, 2
CS	Neg	32	10	65	18	10	12	1, 2
IB	Neg	32	60	22	19	60	12	1, 2
BG	Late	4	5	19	31	15	7	2, 1
RP	Dual	0.5	Col. 1	41	41	5	18	1, 2
RR	Not tested	No reaction	60	5	3	35	6	1, 2
HB	Not tested	No reaction	5	25	—	5	7	1, 2
JB	Not tested	2	Col. 2	29	24	30	0	1, 2
RD	Late	0.5	60	16	6	10	6	2, 1
DP	Not tested	32	Col. 10	12	19	Flux 10	19	2, 1
CS	Not tested	No reaction	60	24	0	60	0	2, 1
EV	Imm.	0.25	10	68	39	15	14	2, 1

tuents of non-corrosive soft-soldering fluxes, and substitute materials for them. This has necessitated giving repeated provocation tests on several days of each of 2–3 successive weeks in individual workers. Such procedures may give reproducible results from day to day. Many subjects become increasingly sensitive with daily provocation testing sufficient to cause significant asthmatic reactions (Herxheimer & Prior, 1952; Connell, 1969) but a few may be hyposensitized, particularly if the provocation tests are spaced a few days apart and insufficient allergen is given to produce an asthmatic reaction (Herxheimer & Prior, 1952). Daily provocation testing in the laboratory parallels the daily exposure at work, where some workers produce equivalent reactions day by day, some become more sensitive day by day and the occasional worker becomes less reactive day by day (Burge *et al.*, 1979b).

This is the first study to compare all the constituents of two commonly used flux cored solders for use in the electronics industry. The fumes from heated colophony are the principal cause of the sensitization. This confirms previous work (Fawcett *et al.*, 1976; Burge *et al.*, 1978). We have compared Portuguese Y colophony with the slightly lower (optical) grade American WW colophony. It would appear that the American colophony causes slightly less reaction in the workers that we have tested. Abietic acid

is the principal resin acid in colophony. We were able to reproduce the asthmatic reactions in all six workers tested with commercial grade abietic acid itself.

It is not clear whether colophony itself is the principal allergen, or whether breakdown products are responsible. Methyl ester of colophony has been tolerated by a violinist with contact dermatitis due to colophony (C. Calnan, personal communication). Fumes from methyl ester of colophony, which are likely to contain similar breakdown products to the unesterified colophony, produced significantly less reactions than colophony with similar levels of fume. When the possibilities for chemical reaction in the glycerol ester of colophony were further reduced by reacting the conjugated double bond system with maleic anhydride, reaction still occurred. However the maleic grouping is likely to react with protein. It seems that a reactive site is needed, but that the reactive site is not itself the main determinant of allergenicity, but takes place in covalent bonding leaving the remaining part of the molecule as a hapten. The unsaturated double bonds of the resin acids seem less important for protein binding than the carboxyl groups. This situation is like that proposed for toluene-diisocyanate sensitivity (Karol, Ioset & Alarie, 1978) where the tolyl group is thought to be the allergenic determinant, the isocyanate group being concerned with protein binding.

The methyl ester of colophony used may have contained up to 5% of unreacted colophony, and the colophony modified by glycerol esterification and reaction of the conjugated double bond system may have contained up to 25% unreacted colophony. This unreacted colophony could explain some of the reactions seen to these two colophony derivatives.

Reactions to the flux activators have not previously been studied. There was a significant correlation between the levels of histamine and flux activator causing reactions, suggesting that these might be acting as non-specific irritants. However, the one worker who had not been exposed to the Multicore activator at work showed specificity in his reaction to the E.G.M. activator alone, suggesting that there was some degree of specificity to the activator fumes.

There is a clear need for substitution of materials used in electronic fluxes, as at present occupational asthma may exceed 20% in factories using mass production techniques (Burge *et al.*, 1979a). There is evidence that this figure would rise if it were not for the high labour turnover, as the mean period between first exposure and sensitization is 4 years, and most workers leave before this time (Perks *et al.*, 1979). Some degree of fume appears necessary at present as one of the actions of the flux is to exclude oxygen from the solder joint. The testing of possible substitute materials in this study can only show if there is cross reactivity with existing materials, or if the materials are primary irritants; prolonged exposure would be needed to assess their potential allergenicity.

It is interesting that seven workers reacted to Zerodor, and flux cored solder with a non-colophony flux. There was a significant correlation between reactions to the flux activator, present in both old and new fluxes, and reactions to the new flux, suggesting that the flux activator might be causing cross reactivity. However, reactions to the new flux were also significantly related to histamine reactivity, suggesting that it could be acting as a non-specific irritant. The paraffin based hot melt glue only resulted in reactions in the two workers with the greatest evidence of non-specific irritability of their airways.

There is reasonable evidence by the three standard criteria that the colophony is

acting as an allergen rather than an irritant in the concentrations encountered at work. Allergens require a period of asymptomatic exposure during which sensitisation takes place. In this group the mean period was 8 years. Only a proportion of exposed workers are affected, although this proportion may be high, as in the electronics industry. Finally reaction may sometimes be induced by very small exposures. In this group two workers required only three breaths and a further four required exposures of 1 min or less. However, so far there are no reports of specific antibody. If colophony was acting as a non-specific irritant there should be a good correlation between histamine and colophony reactivity. This correlation is largely lacking.

The development of colophony substitutes should not be seen as an end in itself. It is likely to give the electronics industry a breathing space during which the standard of occupational hygiene can be improved. It is quite possible that the new substitute materials will prove allergenic. The risk of possible sensitization is likely to be reduced if exposures are minimized. It is unlikely in view of the high degree of sensitivity in some workers that any practical improvement in occupational hygiene standards will allow them to continue using colophony based fluxes.

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