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# ROSIN

## Technical Development Survey Report

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**June 1996**

**DIRECTORATE OF SCIENCE AND TECHNOLOGY**
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# ABSTRACT

The aims of this Technical Development Survey (TDS) were to investigate the pattern and extent of exposure to rosin and its fume and the prevalence of respiratory impairment at selected premises from three different industries: soldering; rosin and rosin solder manufacture and rosin containing hot melt glues in the canning industry.

The methods used to carry out this investigation were:

i. a health questionnaire, based on the Institute of Occupational Medicine (IOM) questionnaire with additional questions to gather information on smoking, occupational history and previous chest illness;
ii. air sampling, using the resin acid method developed by HSL.

Both exposed and non-exposed workers in selected factories from each industry were requested to complete a health questionnaire. In addition personal, static and bulk samples were taken to investigate the levels of exposure to rosin and its fume.

The data collected indicated that the levels of exposure to fume in the soldering industry varied significantly across the sites visited, with an average exposure of 31 $\mu g.m^{-3}$ and a range of 2 $\mu g.m^{-3}$ to 1048 $\mu g.m^{-3}$. Only a minimal level of exposure to rosin was detected in workers in the canning industry, with an average of 2 $\mu g.m^{-3}$. The levels were higher in the manufacturing industry with an average exposure of 21 $\mu g.m^{-3}$. There were higher peak exposures in the manufacturing industry compared with soldering. this suggested more short-term high exposures in manufacturing and more consistent exposures over time in soldering.

The results of the survey suggest that:

- There is clear evidence that exposure to rosin fumes increases the prevalence of at least one of six symptoms amongst females in the soldering industry. This is not the case for male workers in this industry. Nor is it the case for respiratory symptoms alone.
- There is clear evidence that higher exposure levels increase the prevalence of symptoms amongst female workers in the soldering industry with weaker evidence that the same is true for male workers. For both sexes combined there is a significant increase in the prevalence of symptoms as compared with the control workers when exposure levels exceed 50 mg.m-3 .
- The length of time spent in a job with exposure to rosin does not appear of itself to affect the prevalence of job-related symptoms.
- There is some evidence to suggest that the use of engineering controls, local exhaust ventilation in particular, reduces the prevalence of symptoms.

These findings need to be viewed in the context of other survey data on respiratory symptoms in workers exposed to rosin fume (see Rosin-Based Solder Flux Fume Criteria Document - when published).

The report makes recommendations regarding the measurement and control of exposure to rosin and its fume and suggests further work which may provide additional useful information to help reduce the risk of ill-health following exposure to rosin and its fume.

# INTRODUCTION

## Background

The purpose of the Technical Development Survey (TDS) was to investigate the pattern and extent of exposure to rosin and its fume and the prevalence of respiratory symptoms at selected premises where there may be exposure to rosin or its fume.

Rosin is the generic term applied to all natural resins derived from trees of the *Pinus* species. Colophony is an alternative name for rosin, frequently used in connection with solder flux. Much industrial use of rosin involves chemically modified rosin, either as modified rosin or modified rosin esters.

The current method for determining exposure to rosin uses a method for determination of total aldehydes (MBTH method). The results are reported as formaldehyde equivalent. This method is now not considered to be satisfactory as it only measures the gaseous component of the fume. Also, aldehydes are not good markers for measurement of exposure to fume as there is no constant relationship between aldehyde concentration and particulate emission. There is also no direct relationship between respiratory symptoms and rosin core solder pyrolysis product concentration measured as formaldehyde *(Burge et al 1981)*. HSL have developed a new method for the measurement of solder fume (*Pengelly et al 1994a*) which uses resin acids as a marker of exposure to solder fume.

## Objectives

The objectives of the survey were to:

- obtain information about the prevalence of ill-health symptoms in the relevant industries;
- obtain information on current exposure levels, using the newly developed method for sampling and analysis of rosin-cored solder fume;
- obtain information about current control of exposure and identify best practice;
- improve our knowledge and understanding of exposure to rosin in industries other than soldering.

This information will be used to:

- provide information to ACTS/WATCH to enable a practicable and effective exposure standard for rosin-cored solder fume to be prescribed;

- provide FOD with information on current exposures and best practice to control exposure;
- give guidance to FOD on sampling and analysis for rosin;
- provide guidance for industry.

# ROSIN

## Sources

Natural resins are all, with the exception of Lac, of plant origin and usually occur as an exudate of the wood of a variety of species of trees. Rosin is the generic term applied to all natural resins derived from trees of the *Pinus* species. There are three types of rosin: gum, wood and tall oil. They are each obtained by different extractive processes from pine wood.

## Manufacture

Gum rosin is obtained by tapping living pine trees followed by steam distillation of the oleorosin (crude rosin) to separate rosin and turpentine.

Wood rosin is obtained from aged virgin pine stumps which have been allowed to remain in the ground for about 15 years in order that the bark and sapwood decay leaving the heartwood , which is rich in rosin. The stumps are chipped and extracted with hexane or higher boiling point paraffins to give wood rosin, wood turpentine and other turpenes which are separated by fractional distillation. This method of manufacture is rarely used now.

Crude tall oil rosin (the name is derived from the Swedish word tallolja - pine oil) is obtained as a by-product of paper manufacture by the Kraft process, in which pine wood chips are digested to extract the lignin to produce cellulose. Fractional distillation is used to refine the crude tall oil to yield tall oil rosin, tall oil fatty acids, distilled tall oil and tall oil pitch. Each fraction has a wide variety of commercial applications.

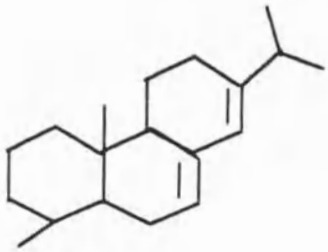
## Chemical Composition

The chemical composition of rosin is complex. The composition and properties of a particular rosin varies depending on the species of timber, growth locality, recovery process, handling, storage and method of preparation. All rosins consist of 90% resin acids and 10% neutral compounds (*Naval Stores 1989*). The structure of some of the main resin acid constituents of rosin are shown in Figure 1. In its natural state laevopimaric acid is the main acid constituent (28-50%) but during processing this changes to its more stable isomer, abietic acid. When rosin is heated to above 175°C the abietic acid proportion increases; above 200°C disproportionation takes place to give mainly dehydroabietic acid with some dihydroabietic acid and tetrahydroabietic acid. One of the most important properties of resin acids is the oxidation by atmospheric oxygen, the abietic type of acid readily takes up oxygen but the pimaric types of acid are relatively inert. Modification by hydrogenation, dehydrogenation and

polymerisation reactions have been shown to reduce the susceptibility to atmospheric oxidation.

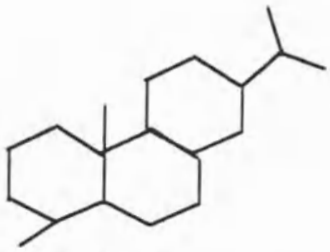
**FIGURE 1**

Main resin acid constituents of rosin



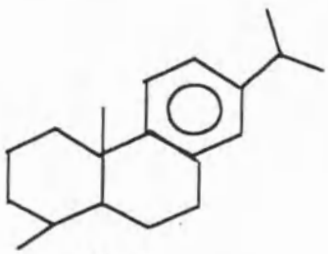
COOH

abietic acid



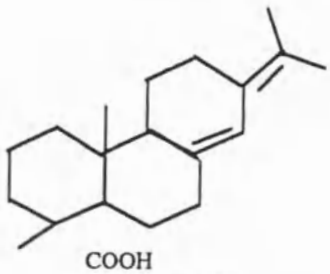
COOH

tetrahydroabietic acid



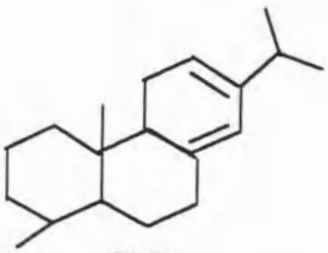
COOH

dehydroabietic acid



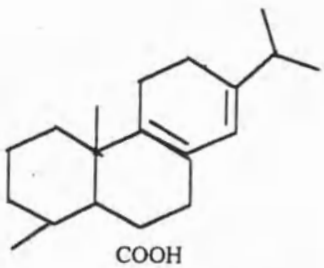
COOH

neoabietic acid



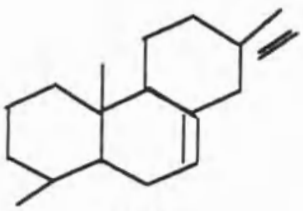
COOH

laevopimaric acid



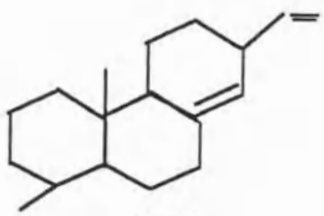
COOH

Palustric acid



COOH

isopimaric acid



COOH

Pimaric acid

**Uses**

Rosins, either gum or tall oil, are used in a wide variety of applications which include:

- soldering;
- surgical plasters;
- glues and adhesives;
- paper size;
- printing inks;
- emulsifiers;
- paints and
- string players rosin.

*Soldering*

One of the most common uses of rosin is in the flux used in soldering. Solder is a tin-lead alloy used to join metal surfaces. Most solder alloys used in electrical and electronic connections are 95% lead and 5% tin. They are used to produce a high melting point solder so that joints formed during the first stage of soldering are not accidentally re-melted during the second stage. Lead free solders are available and are made of tin with approximately 4% silver. Solder melts in the temperature range 200 to 300°C.

Solder wire is produced from an extruded round pipe of the solder alloy with a number of core channels which contain rosin flux. This flux usually consists of rosin to which various activators have been added. The activators, amine hydrohalides and/or organic acids, are incorporated into the rosin at around 170°C and the molten flux is forced through the core channels in the wire. The wire is drawn through progressively smaller dies to produce rosin cored solder wire of the required diameter. The activators are added in relatively small amounts to enhance fluxing action by etching metal oxides from metal contact surfaces on poorly prepared or tarnished metal surfaces. Halide activators are more commonly used in rosin cored solder flux as organic acids have a limited solubility in rosin. The rosin content of a solder wire is dependent on its grade, but is typically 2 to 3%.

Solder flux performs three functions during soldering:

- to react with and remove compounds, eg oxides and sulphides, from the surface of the connection;

- to reduce the surface tension of the molten solder alloy, allowing it to spread quickly and thinly over the metal surface;

- to prevent oxidation during the heating cycle by providing a surface blanket to the base metal and the solder alloy;

There are three main techniques for the application of solder:

- Hand soldering using a soldering iron. Solder wire, which has been heated by the soldering iron to 200 to 450°C, is applied to the connections of an electrical joint.

- Flow (wave) soldering. This method is used in large batch automated production. Assembled circuit boards which have been pre-treated with a solution of flux are mechanically fed over a "standing wave" of molten solder. These processes are usually enclosed.

- Oven baking. A paste of solder metal and flux is applied to the component connections which are then oven baked to melt the solder.

**Health Effects**

The sensitising abilities of rosin have been recognised for a long time; for example allergic contact dermatitis connected with the use of surgical plasters *(Wagg 1993)* and a case of allergic contact urticaria reported following exposure to rosin fume *(Rivers and Ryecroft 1987)*. Exposure to rosin fume is recognised as a significant cause of respiratory sensitisation which can lead to occupational asthma *(Fawcett et al 1976)*. Occupational asthma caused by exposure to solder fume is recognised as a prescribed disease under the Social Security Act 1980; around thirty new cases per annum qualify for disablement benefit *(Health and Safety Statistics 1994/95)*.

Respiratory symptoms were first described at an electronics plant during the 1950s *(Christy 1973)* and were thought to be caused by respiratory irritation. Respiratory sensitisation was demonstrated by Fawcett et al *(1976)* using provocation tests. These findings were confirmed by Burge et al *(1978)* using similar tests. A prevalence study *(Burge et al 1979)* at an electronics factory showed 22% of workers had work-related breathlessness or wheeze or both. In a similar study at a factory making rosin cored solder, 21% of the two highest exposure groups showed respiratory impairment *(Burge et al 1981)*. It was noted that measurements of exposure to rosin cored solder pyrolysis products, using the MBTH method (see below), were all below the current occupational exposure limit. The specific agent (s) that cause sensitisation has/have not been identified. There is some evidence that resin acids are more likely to be the principal causal agent than the gaseous decomposition products *( Burge et al 1986)*.

**Occupational Exposure Limits**

The current UK occupational exposure standard (OES) for rosin cored pyrolysis products (as formaldehyde) is 0.1 mg $m^{-3}$ 8 hour time weighted average (TWA) and 0.3 mg $m^{-3}$ short term exposure limit over 15 minutes *(Health and Safety Executive 1995)*. These limits are to be reviewed by ACTS/WATCH in 1996. The current limits are based on work done in the US by Christy *(1973)* and Melvin et al *(1969)* on which the ACGIH threshold limit value (TLV) was based. ACGIH has a new limit for rosin core solder thermal decomposition products, as resin

acids and is quoted as "sensitiser; reduce exposure as low as possible" (ACGIH TLV Book). Obviously they are also moving towards a measurement method based upon resin acids.

The old ACGIH standard was based upon a judgement of the irritant effects of rosin fume on a group of volunteers during controlled experiments. Aliphatic aldehydes (as formaldehyde) were used as marker substances, as at that time the increasing levels of aldehydes with increased pyrolysis temperatures suggested that this might be the simplest way of monitoring the degree of pyrolysis of the rosin. The measurement of aldehydes as a means of monitoring the level of fume was a pragmatic answer to a difficult problem. At the time, rosin itself was not regarded as sufficiently irritant to account for the effects of the fume. Subsequent work has indicated that in electronics factories correlation between aldehyde levels and the quantity of solder fume in the atmosphere is often poor *(Burge et al 1981, Burge 1982)*. The TLV was originally developed to maintain a level of fume low enough to prevent irritation to eyes, nose and throat. Since the 1970s respiratory sensitisation in soldering environments has increasingly been reported. Also since that time doubt has been expressed that the incidence of respiratory problems bears any relation to the aldehyde levels measured *(Burge et al 1981)*.

**Measurement Methods For Solder Fume**

*MBTH Method*

The MBTH method, based on the method of Christy *(1973)* with minor variations, measures rosin cored pyrolysis products (as formaldehyde) and uses 3-methyl benzothiazole-2-hydrazine hydrochloride (MBTH) to determine total aldehydes *(Turnbull 1991)*. The results are reported as formaldehyde equivalent. Air is sampled into 25 ml impinger tubes containing 10 to 15 ml of MBTH solution at a rate of 0.5 to 1.0 l/minute. Sampling should take place for at least an hour when levels are thought to be low in order to collect enough aldehyde to develop a solution sufficiently coloured for measurement. The aldehyde in the air sampled forms an azine with the MBTH and on addition of an oxidising agent the excess MBTH is oxidised and reacts with the azine to produce a cation which is intensely blue in acid solution. The level of aldehyde is calculated from the spectrophotometric analysis of the colour intensity. This method gives an indication of the total aldehydes present but little is known as to exactly which aliphatic aldehydes are responsible for the blue colour. Different types of solder flux will generate different types of aldehyde and it has also been shown that levels of aldehyde are temperature dependent *(Foster et al 1993)*.

*Resin Acid Method*

The MBTH method for measuring exposure is not now thought to be a satisfactory means of assessing adequate control, as required by COSHH. Therefore a new method for sampling and analysis of solder fume was developed by HSL. Although the composition of rosin is relatively well documented, there is little information on the constituents of solder fume. The first step was to investigate the chemical composition of solder fume to identify those substances which might form the basis of a more meaningful measurement method *(Pengelly et al 1994b)*. They found that the fume constituents depended on the source of the rosin used in the flux; those

investigated contained fluxes based on rosin originating from Portuguese and American sources. Generally solder fume was found to be 90% particulate and 10% gaseous. The exact composition varies, both qualitatively and quantitatively, with temperature. The quantity of fume emitted during soldering depends on a number of variables including wire thickness; metal/flux ratio; flux composition and solder temperature. A reduction of soldering temperature will significantly reduce the quantity of fume *(Wagg 1993)*.

The particulate part of the fume was found to contain the same seven resin acids in all the solder wires tested, with proportions varying between sources:

| Fume Component | Flux of Portuguese origin | Flux of American origin |
|---|---|---|
| Abietic acid | 50% | 42% |
| Palustric acid | 15% | 16% |
| Dehydroabietic acid | 12% | 14% |
| Pimaric acid | 10% | 4% |
| Isopimaric acid | 6% | 15% |
| Neoabietic acid | 5% | 6% |
| Sandaracopimaric acid | 2% | 3% |

Both source types generated predominantly two aliphatic aldehydes in the gaseous part of the fume; formaldehyde and acetaldehyde, the proportions of each varying with temperature. Other volatile components included alpha-pinene, camphene, limonene and fenchyl/bornyl chloride. The gaseous fraction showed the greatest variation in composition between the two types of rosin.

It is thought that resin acids play a role in respiratory sensitisation caused by solder fume. Therefore a method which measures total or specific resin acids in the air would seem to be appropriate for monitoring personal exposure to solder fume. A method has been described by Pengelly et al *(1994b)* where air is drawn through a 13mm Millipore-MF filter at 1 to 2 l/minute to collect the particulate portion of the fume. The samplers can be located either on the lapel or on the side-arm of spectacles. The resin acids retained by the filter are recovered by solvent desorption. After evaporation of the solvent, the resin acids are methylated and quantified by gas chromatography. This method was used in the TDS for sampling during soldering.

## SURVEY METHODS

The aims of this study were to investigate the pattern and extent of exposure to rosin and its fume and the prevalence of respiratory sensitisation in selected premises from three different industries:

- soldering
- rosin and rosin-cored solder manufacture
- rosin containing hot melt glues in the canning industry.

Both exposed and non-exposed workers in selected factories from each industry were requested to complete a health questionnaire. In addition personal, static and bulk samples were taken to investigate the levels of exposure to rosin and its fume.

### Air Sampling

A different sampling regime was used for each of the industries.

*Soldering*

For the soldering industry, long and short term (15 minutes) personal samples were taken to determine 8 hour time-weighted averages (TWA) and peak exposures respectively. The method used a 13 mm Millipore MF membrane filter in a standard Millipore Swinnex 13 mm filter holder, pore size 5.0 μm. The sampling head was placed in the breathing zone, by attaching it at eye level either to the worker's own spectacles or to a pair of safety spectacles. For long term samples, the sampling pump was run at a flow rate of 1 l/min. Short term personal samples were collected using the same type of sampling head at 2 l/min for approximately 15 minutes. Background samples were also taken using a 47 mm Millipore MF filter and a Rotheroe and Mitchell L60 pump.

The aim was to sample the exposure of at least 20% of the workforce. In smaller premises, all of the relevant workers were sampled, exact numbers depended on the size of the workforce.

*Manufacture*

For the rosin manufacturing industry, long and short term (15 minutes) personal samples were also taken. A modified UKAEA sampling head with 7 holes was used, for both long and short-term samples, with a Millipore MF membrane filter, pore size 5.0 μm, at a flow rate of 2 l/min. A charcoal tube was attached in series behind the filter. Short term personal samples were collected using the same sampling head as above, at 2 l/min for approximately 15 minutes. Background samples were taken using 47 mm Millipore MF filters and a Rotheroe and Mitchell L60 pump. The exception to this was Factory 13 where personal samples were taken using 25 mm SM 5.0 μm filters mounted in a modified UKAEA 7 hole sampling head

with charcoal back-up tubes at a flow rate of 1 l/min. Background samples were taken using 60 mm SM 5.0 µm filters with charcoal back-up tubes at a flow rate of 10 l/min.

Bulk samples of the rosin used were taken where possible.

*Canning industry*

For the canning industry long term and personal and background samples were taken. Personal samples were taken using an open faced Gelman sampling head was used with a Millipore MF membrane filter, pore size 5.0 µm, at a flow rate of 1 l/min. A charcoal tube was attached in series behind the filter. Background samples were taken using a 60 mm diameter Millipore MF filter at a sampling rate of 8-10 l/min

Bulk samples of the glues used were taken where possible.

**Analysis of Samples**

Gravimetric analysis was carried out by the FCG. All other analytical procedures were carried out by HSL (see Appendix )

**Health Questionnaire**

The questionnaire (Appendix 2) used in this survey was based on a questionnaire first used by the Institute of Occupational Medicine. As well as the original questions additional information was collected on smoking, occupational history and previous chest illness. The questionnaire was administered by a member of the Employment Medical Advisory Service (EMAS).

All exposed and control workers in factories with a small work force were selected for completion of the health questionnaire. The control workers were those workers who had never had any occupational exposure to rosin fumes, and who worked away from the factory areas where there was likely to be background exposure to rosin fumes. In those factories which had a large number of control workers, an equal number of control and exposed workers were selected randomly. In practice, however, a true random sample of control workers was difficult to obtain, so the best attempt at a random sample was allowed. All workers were allocated a job code according to a previously defined list of activities (Appendix 3).

**Statistical Techniques**

Odds ratios and their corresponding confidence intervals were calculated using logistic regression carried out in GLIM[3]. Where cell numbers were too small for the chi-squared test (i.e. less than 5) exact methods were used to estimate the odds ratios and their confidence intervals. This was done using the packages Statxact[4] and Logxact[5].

All significance tests were performed at the 5% level.

## Validation

Workers from only one factory in the rosin-cored solder manufacture industry completed the questionnaire. This, in turn, produced returns from only 2 exposed and 2 control workers. For this reason, in all subsequent analysis, the workers in the rosin-cored solder manufacturing industry are grouped with the workers in the rosin manufacturing industry. This new grouping is called 'Manufacturing' in all analysis by industry type.

At several points within the questionnaire, questions should have been skipped if the previous question had been answered in a particular way. During the validation of the data, those answers which were completed when they should have been skipped were investigated. To avoid introducing any bias into the data, those questions which should not have been answered due to previous responses were set to blank. Furthermore, on examination, there were some control workers who had responded to the questions on occupational history by listing a job within a rosin exposed environment. These workers could no longer be considered as controls and were subsequently excluded from the analysis.

## RESULTS

A summary of the results is given here. The complete reports from both EMSU and HSL are given in the Appendices.

### Air Sampling

Where results were below the limit of detection, a value of half the limit of detection was used in the statistical analyses.

*Soldering Industry*

The personal sampling results, shown in Table 1 are in ug.m$^{-3}$ of total resin acids and are all 8hour TWAs.

**Table 1**

| Company | Geometric Mean | Minimum | Maximum | Number of Samples | Control |
|---|---|---|---|---|---|
| 18 | 62 | 24 | 197 | 9 | - |
| 19 | 215 | 58 | 781 | 11 | - |
| 21 | 26 | 3 | 1,048 | 11 | lev |
| 22 | 37 | 2 | 1,001 | 6 | exhaust nozzle on iron |
| 23 | 43 | 16 | 131 | 8 | - |
| 24 | 8 | 2 | 20 | 6 | lev |
| 25 | 6 | 2 | 10 | 11 | lev |
| 27 | 90 | 7 | 637 | 11 | fan |

At all of the companies hand soldering was the predominant occupation that was sampled. There was a small amount of flow soldering being done at Company 19, where 1 sample was taken during this work. The exposure here was relatively high (529 µg.m-3) but the operator spent some of the sampling time cleaning the machine.

The time spent soldering varied from person to person. No-one spent 100% of their time soldering. Time spent soldering varied from 25 to 75% of the day. The other jobs carried out include:

tinning wires;
trimming ends of components;
stripping wires;
desoldering;
assembling parts.

The type of work carried out during the sampling periods was taken to be representative of the whole day and therefore the results from these sampling periods were used as 8 hour TWAs.

With one exception, the geometric means of the sampling results were all below 100 μg.m-3. At Company 19 the relatively high results may be due to the fact that the work area had a number of zones in which it would be difficult to get air to circulate, due to the layout of the workstations.

At Company 27 small fan units were used to draw the fume away from the operator. These units had a filter coated with activated charcoal. Their effectiveness in removing fume from the operator seems doubtful and it seems likely that a substantial proportion of the fume was released back into the workroom as this type of filter does not remove particulates. This may explain the relatively high levels at this site.

There are a few anomalies in the results: at Companies 21 and 22 the geometric means are relatively low but at each site there was one very high result. Both high results are over 1000 $\mu g.m^{-3}$ . However at both sites operators carrying out the same jobs as the ones with very high exposures had substantially lower results (less than 100 $\mu g.m^{-3}$). There appeared to be no obvious reasons for these discrepancies.

The overall picture is that in general, exposures to solder fume are reduced when some form of engineering control method is used

*Manufacturing*

The manufacturing companies either process rosin in some way or make rosin core solder:

| | |
|---|---|
| Company 10 | manufactures modified rosin from imported rosin; |
| Company 11 | extracts rosin from tall oil; sells this as solid rosin or pellets and manufactures modified rosin; |
| Company 12 | processes molten tall oil rosin to produce a rosin emulsion which is used in the paper industry to provide water resistance without loss of strength; |
| Companies 13 and 14 | manufacture rosin core solder. |

The personal sampling results for companies 11, 12 ,13 and 14 are shown in Table 2. They are all 8hour TWAs in $ug.m^{-3}$ of total resin acids.

**Table 2**

| Company | Geometric Mean | Minimum | Maximum | Sample Size |
|---|---|---|---|---|
| 11 | 26.4 | 2.9 | 1,361 | 22 |
| 12 | 3.9 | | | 1 |
| 13 | 12.5 | 2.6 | 235 | 12 |
| 14 | 423 | | | 1 |

At Company 11 exposures are likely to occur:

- during loading and off-loading of tall oil to and from road tankers.
- to process operators, especially when taking samples and loading the molten rosin into road tankers for transport to the modified rosin plant.
- during bagging of pellets.
- capping filled barrels after they have been filled with molten rosin.

The highest exposures were seen in people who carried out the charging of rosin, taking samples and bagging pellets.

At Company 12 exposures to molten rosin are likely to occur:

- at the addition of maleic anhydride. This operation lasted for approximately 20 minutes, once a day and the reaction vessel was under negative pressure. Exposure for this task was below the limits of detection (not shown in table).
- during the emulsification process when casein is added and the batch is mixed in a "Bewoid pot".

At Company 13 exposures to rosin are likely to occur:

- during breaking and weighing of raw rosin.
- loading mixers with rosin and other chemicals.
- during breaking up and scooping of solid flux during extrusion.
- soldering of ends of successive batches of extruded wire.

The highest exposures occurred during loading of mixers and during breaking and weighing of raw rosin. Although the mixing machines did have extraction it did not appear to be particularly efficient.

At Company 14 only one personal sample was taken as there was only one process operator. A number of static samples were taken at points as near as possible to where exposures could occur. The personal sample (423 $\mu g.m^{-3}$) taken appears to be much higher than the background sample (7.9 $\mu g.m^{-3}$ ) which was placed next to the charger on the flux machine, where greatest exposures would have been expected. As the operator does not remain in close proximity to the machine at all times it may be that the material collected on the personal sampler is solid rosin dust which landed on the sampler during scooping of the material from the drum to the charger.

At Company 10 solid unmodified rosin is broken up manually then fed into a vessel, melted to 150°C and pumped to a reaction vessel where chemical additions are made and the reactions take place at 250-270°C. The modified rosin is pumped to a holding tank and cooled to a temperature at which it is just fiuid and then is run off into multi-ply bags. The weight of each bag is adjusted by breaking up the solid modified rosin. Exposures to rosin could occur at:

- breaking up and loading of unmodified rosin (dust);
- running off of molten modified rosin into sacks (fume);
- cleaning out of the holding tanks (dust) and

- weight adjustment of sacks (dust).

The results from Company 10 are not shown in Table 2 (above) as all the exposure results obtained there were related to specific tasks and it was not possible to determine 8hour TWAs at this company as the work routine was very variable.

The personal sampling results for Company 10 are shown in Table 3.

**Table 3**

| Activity | Result ($\mu g.m^{-3}$) | Time (minutes) | RPE |
|---|---|---|---|
| Bagging of molten rosin | 835 | 54 | - |
| Bagging of molten rosin | 1,268 | 54 | - |
| Bagging of molten rosin | 1,461 | 51 | - |
| Bagging of molten rosin | 810 | 61 | - |
| Manual breaking up of solid rosin/charging melting vessel | 2,813 | 48 | disposable filtering facepiece respirator |
| Manual breaking up of solid rosin/charging of melting vessel | 2,020 | 46 | disposable filtering facepiece respirator |
| Charging of melting vessel | 200 | 130 | disposable filtering facepiece respirator |
| Charging of melting vessel | 233 | 131 | disposable filtering facepiece respirator |
| Tank cleaning | 3,704 | 20 | RQ Supa 2000/90l orinasal respirator |
| Tank cleaning | 3,753 | 27 | RQ Supa 2000/90l orinasal respirator |

*Canning*

Hot melt glues containing rosin are used in the canning industry to stick the leading edge of the label to the can. The trailing edge of the label is then overlapped and stuck using a water based adhesive. After labelling cans pass on to a packing machine. Each labelling machine has a glue pot which is replenished by adding solid flakes of glue when necessary. Adding flakes of the glue usually only took a few seconds. A single operator usually supervises each labelling machine; inserting labels and filling the glue pot, and carries out this job all day except for

breaks. Generally other people working on the packing and assembly lines move from one task to another at regular intervals. The glue pots are enclosed but none were extracted. The amount of glue applied to each label was very small and the setting rate is rapid. No RPE was used.

Table 4 gives the personal sampling results from the use of hot melt glues in the canning industry. All are 8 hour TWAs and are in $\mu g.m^{-3}$ of total resin acids.

**Table 4**

| Company | Result | Number of Samples | Job |
|---|---|---|---|
| 15 | below limitof detection | 4 | 1 labeller and 3 general operators |
| | 5.43 | 1 | general operator |
| | 3.91 | 1 | general operator |
| 16 | below limit of detection | 6 | 1 labeller and 5 general operators |
| 17 | below limit of detection | 5 | 1 labeller and 4 general operators |
| | 4.34 | 1 | general operators |

The limit of detection for these samples was 2.5 $\mu g.m^{-3}$

**Health Questionnaire**

*Soldering Industry*

After controlling for the effects of age and smoking status, there was a significantly higher proportion of exposed workers reporting at least one symptom compared to the control workers. This difference, however, was only evident amongst the female workers. There was no indication of any significant excess of symptoms amongst the exposed males. There is no obvious explanation for this variance in the levels of symptoms between the two sexes. There was no significant difference between the numbers of exposed and control workers reporting at least one respiratory symptom. Furthermore, the amount of time spent in a job with exposure to rosin fume appeared to have no effect on the number of reported symptoms.

*Canning Industry*

There was no significant difference between the numbers of exposed and control workers in this industry reporting at least one symptom or at least one respiratory symptom for either males or females. Small numbers in this industry prohibited the examination of the effects of age and smoking status on these results.

*Manufacturing Industry*

All questionnaires returned from workers in this industry were from men. There was no significant difference between the number of symptoms reported by the exposed and control workers. This was the case for all the individual symptoms. Again, small numbers in this industry prohibited the examination of the effects of age and smoking status.

# DISCUSSION

## Factors Relating to Ill-Health

The first objective of this survey was to obtain information about the prevalence of ill-health in the relevant industries. To some extent we did achieve this objective, even though the study was relatively small. Small numbers limited the amount of useful data that could be obtained from both the manufacturing and canning industries.

The survey provides some evidence that exposure to rosin fumes increased the prevalence of at least one of the six symptoms amongst females in the soldering industry. This was not the case for respiratory symptoms alone. Nor was the same effect shown amongst males. There is no obvious explanation for the differing results between females and males.

There is also some evidence that higher exposure levels increases the prevalence of symptoms amongst female workers in the soldering industry with weaker evidence that the same is true for males in this industry. For both sexes combined there is a significant increase in the prevalence of symptoms as compared with the control workers when exposure levels exceed 50 $\mu g.m^{-3}$.

The amount of time spent in a job with exposure to rosin fumes does not of itself appear to affect the prevalence of job-related symptoms. There was also no correlation between peak levels of exposure and symptoms in the soldering industry. There is some evidence to suggest that the use of ventilation equipment, LEV in particular, reduces the prevalence of symptoms

These findings need to be viewed in the context of other survey data on respiratory symptoms in workers exposed to rosin fume. For further information see the Rosin-Based Solder Flux Fume Criteria Document. This document has not yet been published but will be available when the new limit has been approved.

## Current Exposure Levels

The second objective was to obtain information on current exposure levels using the new measurement method. This objective was also achieved. We now have some information regarding exposures in canning and manufacture however, we have much more information on exposures during hand soldering.

### *Soldering*

The levels of exposure to rosin in the soldering industry varied significantly across the factories but not the sexes, with an average exposure of 31 $\mu g.m^{-3}$ and a range of 2 $\mu g.m^{-3}$ to 1,048 $\mu g.m^{-3}$. As would be expected, the results of the air sampling show that the use of some form of engineering control reduces exposure. LEV would appear to be most useful in reducing exposure, whilst the use of on-iron extraction does reduce exposure to a lesser extent. This may be due to the fact that on-iron extraction needs to be very regularly maintained and cleaned to operate efficiently, the nozzle very easily becomes clogged with

rosin. The use of extraction fans to remove the fume from the solderers does not appear to be particularly effective. This may be due to the low capture efficiency of the unit and/or the fact that a large proportion of the fume appears to be put back into the workplace, thus also increasing exposure to the non-solderers in the workroom. Exposures in general are higher where there is no engineering control. Other factors, such as the lay-out of the workroom and methods of working, in some cases exacerbate exposures.

*Manufacturing*

In the manufacturing industry the levels were higher than the canning industry (see below) with an average exposure of 21 $\mu g.m^{-3}$ and with a range of 2.9 to 1361 $\mu g.m^{-3}$ for long term exposures . Exposures in this industry were either to rosin dust or to rosin fumes, unlike soldering and canning where exposures were to fume only. There were higher peak exposures in the manufacturing industry compared with the soldering industry. This suggested more short-term high exposures in the manufacturing industry and more consistent exposures over time in the soldering industry. RPE was not used in the soldering industry, whereas in manufacturing RPE was used where exposures were perceived to be potentially high. The choice of RPE in some companies needs to be re-assessed in light of the sampling results presented here.

*Canning*

Only minimal levels of rosin exposure were detected in workers in the canning industry, with an average of 2 $\mu g.m^{-3}$. There are a number of possible reasons for this:

- that exposures are low in this industry possibly due to the short amount of time operators spend near or at the hot melt glue pot;

- hot melt glues are used at a much lower temperature (approx 100°C) than solder irons and consequently may give off less fume;

- the sampling method may not be appropriate for this industry - hot melt glues are generally made from modified rosins and the sampling method was designed for unmodified rosins in solder fume.

*Control*

The third objective was to obtain information on control and identify best practice. The results from the soldering industry indicate that some form of engineering control reduces exposures significantly. LEV appears to be the best form of engineering control with the use of extraction fans to draw fume away from the operator being counter-productive in that they appear to be very efficient at spreading the fume around the workroom.

*Further Information in Manufacturing and Canning*

The final objective was to improve our knowledge and understanding of exposure to rosin in industries other than soldering. We have got some information which tells us something about exposures in the manufacturing and canning industries.

The manufacturing sites visited in the survey were, as far as we know, all the sites in this country which manufacture rosin or rosin solder. We have exposure data from one manufacturing site where the completed questionnaires were not available for analysis. The exposure data should be useful in allowing re-assessment of the different tasks undertaken in this industry in terms of usefulness of control measures.

The visits to the canning industry did not provide much information on ill-health effects as we only visited three sites. The results from the questionnaires can be compared with the results of a previous survey carried out by Dr Wright from Norwich EMAS. This study found that exposed workers had a higher prevalence of irritant symptoms than the control group. The differences were not significant except for the number of exposed workers with more than one symptom.

## RECOMMENDATIONS / FUTURE WORK

- The information acquired during this TDS, both air sampling and health data, will be used as part of the submission to ACTS/WATCH.

- Account should be taken of the findings of this TDS in the deliberations of ACTS/WATCH in the setting of an occupational exposure limit for solder fume.

- The resin acid measurement method, developed by HSL, should be used in future as the method for estimating exposure to solder and rosin fumes.

- A MDHS should be prepared to give guidance on sampling and analysis for solder fume.

- The information in the TDS should be used to inform debate with industry in the production of guidance, currently being discussed with the Engineering NIG led Soldering Joint Working Group.

- Further work needs to be carried out to determine what are the constituents of hot melt glue fume and to develop a sampling method which accurately reflects what is in the fume

- Further work needs to be carried out on the efficacy and efficiency of engineering controls, particularly extraction fans.

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# APPENDIX 1

# EMSU REPORT

# Rosin (Colophony) Technical Development Study


## Summary

Rosin is the generic term applied to all natural resins from trees of the *Pinus* species. Colophony is an alternative name for rosin, frequently used in connection with solder flux. Solder fume is a known respiratory sensitiser, and accounts for about 10% of occupational asthma compensation claims. The aims of this study were to investigate the pattern and extent of exposure to rosin and its fume and the prevalence of respiratory and skin symptoms in selected premises from three different industries:

i) Soldering
ii) Rosin and rosin-cored solder manufacture
iii) rosin containing hot melt glues in the canning industry.

Both exposed and non-exposed workers in selected factories from each industry were requested to complete a health questionnaire. In addition personal samples were taken from selected workers to investigate the levels of exposure to rosin and its fume.

**Canning Industry:**

There was no significant difference between the numbers of exposed and control workers in this industry reporting at least one symptom or at least one respiratory symptom for either males or females. Small numbers in this industry prohibited the examination of the effects of age and smoking status on these results.

**Manufacturing Industry:**

All questionnaires returned from workers in this industry were from men. There was no significant difference between the number of symptoms reported by the exposed and control workers. This was the case for all the individual symptoms. Again, small numbers in this industry prohibited the examination of the effects of age and smoking status.

**Soldering Industry:**

After controlling for the effects of age and smoking status, there was a significantly higher proportion of exposed workers reporting at least one symptom compared to the control workers. This difference, however, was only evident amongst the female workers. There was no indication of any significant excess of symptoms amongst the exposed males. There is no obvious explanation for this variance in the levels of symptoms between the two sexes. There was no significant difference between the numbers of exposed and control workers reporting at least one respiratory symptom. Furthermore, the amount of time spent in a job with exposure to rosin fume appeared to have no effect on the number of reported symptoms.

**Exposure Data**

Only a minimal level of rosin exposure was detected in workers in the canning industry, with an average of 2 $\mu g/m^3$. In the manufacturing industry the levels were higher with an average exposure of 21 $\mu g/m^3$. The levels of exposure to rosin in the soldering industry varied significantly across the factories but not the two sexes, with an average exposure of 31 $\mu g/m^3$

and a range of 2 $\mu g/m^3$ to 1,048 $\mu g/m^3$. There were higher peak exposures in the manufacturing industry compared with the soldering industry. This suggested more short-term high exposures in the manufacturing industry and more consistent exposures over time in the soldering industry.

There was no correlation between peak levels of exposure and number of symptoms in the soldering industry.

From the long-term samples, there is evidence that higher exposure levels increase the prevalence of symptoms amongst female workers in the soldering industry and some evidence that the same is true for male solderers. The exposure level at which the prevalence of symptoms becomes significantly higher amongst exposed workers in the soldering industry appears to be 50 $\mu g/m^3$. This would seem to be the appropriate level at which to set a control measure.

There was also some evidence of reduced levels of symptoms amongst male and female workers who had access to some form of control equipment when soldering. This was particularly true for females using local exhaust ventilation when soldering.

# Rosin (Colophony) Technical Development Study

## 1) Background and Objectives

1.1 Rosin is the generic term applied to all natural resins from trees of the *Pinus* species. Colophony is an alternative name for rosin, frequently used in connection with solder flux. Solder fume is accepted as a respiratory sensitiser[1], and accounts for about 7% of occupational asthma compensation claims (34 cases in 1993)[2].

1.2 The aims of the Technical Development Study were as follows:

i) To obtain information about current control of exposure and identify best practice.

ii) To obtain information about the prevalence of respiratory sensitisation in the relevant industries and to increase the awareness of users to potential risk.

iii) To provide information to ACTS/WATCH and industry organisations to enable a practicable and effective standard to be prescribed.

iv) To give guidance to FOD on current exposures and best available practice to control exposure as well as methods of sampling and analysis.

1.3 EMSU's role in the TDS was to co-ordinate the design of the questionnaire and analyse both the questionnaire data and the sampling data linked to the findings of the questionnaire.

## 2) Methods

### 2.1 Population and Sampling Methods

2.1.1 The survey was split into three specific industries:

i) soldering
ii) rosin and rosin-cored solder manufacture
iii) rosin containing hot melt glues in the canning industry

2.1.2 All but one of the factories selected for investigation in the soldering industry was based in the West Midlands area, with the remaining factory, factory 27, being in the North East. All premises selected in the canning industry were in the Norwich area. The factories selected in the manufacturing industry were split between the South East, the Home Counties (North), the North East and the North West.

2.1.3 All exposed and control workers in factories with a small work force were selected for completion of the health questionnaire. The control workers were those workers who had never had any occupational exposure to rosin fumes, and who worked away from the factory areas where there was likely to be background exposure to rosin fumes. In those factories which had a large number of control workers, an equal number of control and exposed workers were selected randomly. In practise, however, a true random sample of control workers was difficult to obtain, so the best attempt at a random sample was allowed. All workers were allocated a job code according to a previously defined list of activities (Annex A). This list was used to code

the job history of a worker in the health questionnaire and to link sampling results to work activity.

## 2.2 Health Questionnaire

2.2.1 The questionnaire was based on a questionnaire first used by the Institute of Occupational Medicine. As well as the original questions additional information was collected on smoking, occupational history and previous chest illness (Annex B). The questionnaire was administered by a member of the Employment Medical Advisory Service (EMAS).

## 2.3 Hygiene Measurement

2.3.1 A different sampling regime was required for each of the industries.

2.3.2 For the soldering industry, long and short term (15 minutes) personal samples were taken to determine 8 hour time-weighted averages (TWA) and peak exposures. The method used a 13mm Millipore MF membrane filter in a standard Millipore Swinnex 13mm filter holder, pore size 5.0 μm. The sampling head was placed in the breathing zone, i.e. attached at eye level either to the worker's own spectacles or to a pair of safety spectacles. For long term samples, the sampling pump was run at a flow rate of 1 l/min. Short term personal samples were collected using the same type of sampling head at 2 l/min for approximately 15 minutes.

2.3.3 For the rosin manufacturing industry, long and short term (15 minutes) personal samples were also taken. A modified UKAEA sampling head with 7 holes was used with a Millipore MF membrane filter, pore size 5.0 μm, at a flow rate of 2 l/min. A charcoal tube was attached in series behind the filter. Short term personal samples were collected using the same sampling head as above, at 2 l/min for approximately 15 minutes.

2.3.4 For the canning industry, again, long and short term (15 minutes) personal samples were taken. An open faced sampling head was used with a Millipore MF membrane filter, pore size 5.0 μm, at a flow rate of 1 l/min. A charcoal tube was attached in series behind the filter. Short term personal samples were collected using the same type of sampling head with charcoal tube as before, at a flow rate of 1 l/min for 15 minutes.

## 2.4 Statistical Techniques

2.4.1 Odds ratios and their corresponding confidence intervals were calculated using logistic regression carried out in GLIM[3]. Where cell numbers were too small for the chi-squared test (i.e. less than 5) exact methods were used to estimate the odds ratios and their confidence intervals. This was done using the packages Statxact[4] and Logxact[5].

2.4.2 All significance tests were performed at the 5% level.

## 2.5 Validation

2.5.1 Workers from only one factory in the rosin-cored solder manufacture industry completed the questionnaire. This, in turn, produced returns from only 2 exposed and 2 control workers. For this reason, in all subsequent analysis, the workers in the rosin-cored solder manufacturing

industry are grouped with the workers in the rosin manufacturing industry. This new grouping is called 'Manufacturing' in all analysis by industry type.

2.5.2 At several points within the questionnaire, questions should have been skipped if the previous question had been answered in a particular way. During the validation of the data, those answers which were completed when they should have been skipped were investigated. To avoid introducing any bias into the data, those questions which should not have been answered due to previous responses were set to blank. Furthermore, on examination, there were some control workers who had responded to the questions on occupational history by listing a job within a rosin exposed environment. These workers could no longer be considered as controls and were subsequently excluded from the analysis.

## 3) Results

### 3.1 Respondent Characteristics

3.1.1 Table 1 gives the number of workers in the study broken down into exposure category, sex and age for each industry. Four respondents failed to give their date of birth, and so no age is recorded.

**Canning Industry**

3.1.2 There were significantly more women than men selected from the canning industry, but the male:female split was consistent for both the exposed and control workers. There was an equal proportion of exposed and control workers who responded. Amongst the exposed workers, the females were in general older than the males, whereas they were younger amongst the control workers. Furthermore, the exposed males were younger than the male control workers, whilst the exposed and control females were of roughly the same age.

**Manufacturing Industry**

3.1.3 In the manufacturing industry there were no exposed females who completed a questionnaire, although nearly half of the controls from this industry were female. There was an equal proportion of exposed and control workers who responded. The exposed males were, in general, older than the male controls. The male and female control workers were of a similar age distribution.

**Soldering Industry**

3.1.4 In the soldering industry there were significantly more exposed females than males, a pattern not seen amongst the controls. There was also a much larger proportion of exposed respondents, with nearly 75% of workers questioned being exposed to rosin fume. This was due to the size of the factories in the soldering industry making a 1:1 sample too time consuming. Amongst the exposed workers, the females were in general older than the males, whereas the split was not pronounced amongst the control workers. Furthermore, the exposed males were younger than the male control workers, whilst the exposed and control females were of roughly the same age.

3.1.5 Due to the differences between the respondent characteristics for the three industries seen here, future analysis will be split by industry and sex. This also allows for more emphasis to be placed on the analysis of workers in the soldering industry, something subsequently decided by the TDS co-ordinators.

3.1.6 The smoking profile of the workers is more consistent across sex and exposure group for the three industries (table 2). Amongst the exposed workers, there is a consistently higher number of non-smokers compared to smokers, with a smaller number again of ex-smokers. Amongst the control workers, there seems to be more ex-smokers than is the case for the exposed workers, particularly amongst females in the soldering industry, who have a higher proportion of ex-smokers to smokers.

3.1.7 Table 3 lists the number of exposed workers according to sex, industry and job. For the purposes of this table the manufacturing industry is split up into rosin and rosin-cored solder manufacture. The ratio of males to females in the canning industry is approximately 1:2, with the majority (two-thirds) of the workers being labellers. There were no exposed females selected from the manufacturing industry indicating that the shop floor work in this industry is almost entirely male dominated. The majority of the workers in the manufacturing industry were process operators of some sort. Nearly 80% of all questionnaires were taken from workers in the soldering industry of which 65% were women.

### 3.2 Questionnaire Data Analysis

3.2.1 Tables 4 - 8 report the number and type of symptoms reported by the workers. Two definitions of 'occupational' were examined: a 'tight' and 'loose' definition. For the 'tight' definition, only those workers who said their symptom was less likely to occur when on holiday for a week or more were defined as having an occupational symptom. For the 'loose' definition, the presence of a certain symptom was defined as occupational if the symptom was less likely to occur when on holiday for a week or more *or* was neither less or more likely to occur when on holiday. This 'loose' definition ensures that no workers with occupational symptoms are missed, but will clearly over estimate the prevalence of occupational symptoms, whereas the 'tight' definition would under estimate the prevalence of occupational symptoms.

3.2.2 Six symptoms were defined from the questionnaire results as follows:

| Symptom | Definition |
|---|---|
| Chronic Bronchitis | Positive answer to both questions 1 and 2 on the questionnaire |
| Cough attacks | Positive answer to question 3 |
| Chest problems | Positive answer to either question 7 or question 8 |
| Nasal problems | Positive answer to question 12 |
| Eye problems | Positive answer to question 18 |
| Hand problems | Positive answer to question 22 |

3.2.3 Table 4 compares the prevalence of symptoms for the two aforementioned definitions of 'occupational': the 'loose' definition and the 'tight' definition, and also for all workers, irrespective of improvements in symptoms when on holiday. Chronic bronchitis had no questions relating to occupation. There is clearly a sharp reduction in the prevalence of symptoms between the 'loose' and 'tight' definitions for both the exposed and control workers in all three industries. There is, furthermore, very little difference between the levels of symptoms for all cases and the 'loose definition'. It was therefore decided to analyse all cases reporting symptoms, irrespective of the change in symptom when on holiday or not. Although this will over estimate the prevalence of occupational symptoms, the comparison with the control workers should help to eliminate this effect.

3.2.4 Table 5 shows the numbers and percentages of those workers reporting one or more of the six symptoms, split by the three industries and sex.

**Canning Industry**

3.2.5 The table below summarises the prevalence of symptoms for male and female exposed and control workers in the canning industry.

| Sex: | Males | | Females | |
|---|---|---|---|---|
| Symptoms: | ≥ 1 Symptom | ≥ 1 Respiratory Symptom | ≥ 1 Symptom | ≥ 1 Respiratory Symptom |
| Controls | 44% | 33% | 48% | 30% |
| Exposed | 67% | 50% | 65% | 50% |

3.2.6 It can be seen from table 5 and figure 1a that, although there is, for the majority of the symptoms, an increased prevalence of symptoms amongst the exposed workers, all but one of these increases are not significant. The exception being hand problems for males and females combined. The fact that there are over 20 different comparisons being made means we would expect at least one comparison to be significant anyway. The small number of workers in this industry prohibits any further breakdown of the figures.

**Manufacturing Industry**

3.2.7 All the exposed workers returning a questionnaire from the manufacturing industry were male. The percentage of workers reporting at least one (respiratory) symptom are summarised as follows:

| Symptoms: | ≥ 1 Symptom | ≥ 1 Respiratory Symptom |
|---|---|---|
| Controls | 43% | 7% |
| Exposed | 50% | 21% |

3.2.8 These differences are not significant. Furthermore, none of the individual symptoms showed a significantly different prevalence between the exposed and control workers (table 5 and figure 1b). Once again, the small number of workers in this industry precludes any more detailed analysis.

**Soldering Industry**

3.2.9 The corresponding figures for workers in the soldering industry are as follows:

| Sex: | Males | | Females | |
|---|---|---|---|---|
| Symptoms: | ≥ 1 Symptom | ≥ 1 Respiratory Symptom | ≥ 1 Symptom | ≥ 1 Respiratory Symptom |
| Controls | 70% | 35% | 62% | 33% |
| Exposed | 56% | 39% | 79% | 49% |

3.2.10 It is surprising to see that the exposed males had a smaller percentage of at least one symptom than the controls (table 5 and figure 1c). In fact, of the six individual symptom categories, the exposed males have a lower rate than the controls for four of them. This is, however, not the case for the females, for whom the exposed workers have a consistently higher prevalence of symptoms compared to the control workers. Furthermore, there is a significantly higher number of exposed females with at least one symptom compared with the control workers. This is also the case for nasal problems. This significant increase for nasal problems is also manifest when the males and females are combined, with the prevalence of chronic

bronchitis also becoming significantly higher amongst the exposed workers when the two sexes are combined.

3.2.11 Looking at the specific jobs carried out by the workers in the soldering industry, the following table lists the rosin-related activities specified by exposed workers for each symptom as making their condition worse:

| Symptom | Job activity | Males | Females |
|---|---|---|---|
| Cough attack | Manual soldering | 3 | 9 |
| | Automatic soldering | | 1 |
| | Assembling components after soldering | 1 | 2 |
| Chest problems | Manual soldering | 9 | 11 |
| | Preparing components for soldering | 2 | 1 |
| Nose problems | Manual soldering | 4 | 14 |
| | Tinning | | 2 |
| | Preparing components for soldering | 1 | 3 |
| | Assembling components after soldering | | 3 |
| Eye problems | Manual soldering | 3 | 10 |
| | Assembling components after soldering | | 1 |
| Hand problems | Manual soldering | | 1 |
| | Preparing components for soldering | | 2 |
| | Assembling components after soldering | 2 | 4 |

3.2.12 It is clear from this table that the activity which caused the most problems was the actual soldering itself, except for hand problems which were most frequently brought on when assembling components after soldering.

3.2.13 Tables 6.1 and 6.2 define the prevalence of symptoms amongst solderers by sex and smoking status. Amongst the control workers, there seems to be little difference between the levels of symptoms for the three smoking categories, for either of the sexes (table 6.1). However, for the exposed workers, there is a significantly higher level of at least one respiratory symptom amongst male smokers and ex-smokers compared to their equivalent non-smokers; this is also the case for female smokers compared to non-smokers. Logistic regression, however, does not indicate any significant interaction between the control and exposed workers and the three smoking groups when modelling the prevalence of symptoms.

3.2.14 An additional confounding factor in the prevalence of symptoms could be the age of the worker. Table 7 examines the number of symptoms occurring amongst solderers split by age. There is no clear pattern in the prevalence of either respiratory or all symptoms amongst the control or exposed workers. This is confirmed by logistic regression, showing no significant differences in symptom levels for the five age groups and the two sexes. Controlling for age maintains the pattern in the symptoms seen previously.

3.2.15 If the effects of both age and smoking status are controlled for, and looking at the presence of at least one symptom, there is still a significant difference between the exposed and control groups. This is, however, only true for the females. When looking at the presence of at

least one respiratory symptom, however, there is no evidence of any significant difference between control and exposed workers.

3.2.16 In order to assess the amount of time exposed to rosin a crude definition of length of exposure was derived. To calculate the duration of exposure, the amount of time spent by a worker in up to their last three jobs with some exposure to rosin fumes was calculated. It can be seen (table 8) that there is no evidence of an positive relationship between length of time in an exposed job and the prevalence of symptoms. None of the differences in the number of symptoms across the lengths of exposure are significant.

3.2.17 Workers were asked on the questionnaire to list the number of times they had been off work in the last 3 years, and the condition which affected them. The following table lists the different conditions for which absence was reported for exposed workers:

| **Number of times off work:** | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| **Sex:** | **Illness:** | | | | | | |
| **Male** | Asthma | 0 | 2 | 0 | 0 | 0 | 0 |
| | Bronchitis | 2 | 1 | 1 | 0 | 0 | 0 |
| | Cold | 2 | 1 | 1 | 0 | 0 | 0 |
| | Flu | 3 | 4 | 0 | 0 | 0 | 0 |
| **Female** | Asthma | 2 | 4 | 2 | 0 | 0 | 0 |
| | Bronchitis | 4 | 3 | 0 | 0 | 0 | 1 |
| | Cold | 9 | 2 | 3 | 2 | 0 | 0 |
| | Flu | 8 | 2 | 3 | 0 | 0 | 0 |

3.2.18 It can be seen from this table that colds and influenza amongst the females are the most common illnesses, with the one notable outlier being the woman who has been off six times with bronchitis. This woman was an assembler and ex-smoker.

### 3.3 Exposure Data

3.3.1 The following table lists the 8 hour time weighted average (TWA) exposures to rosin in $\mu g/m^3$ by sex and industry. Due to the highly skewed nature of all the TWA data, the correct statistic to use for a measure of average and dispersion of the data is the geometric mean and standard deviation (SD):

| Industry: | | Manufacturing | | Canning | | Soldering | |
|---|---|---|---|---|---|---|---|
| Sex: | | Male | Female | Male | Female | Male | Female |
| Number | | 20 | 1 | 6 | 12 | 13 | 57 |
| Maximum value | | 1,361 | 3 | 4 | 5 | 530 | 1,048 |
| Minimum value | | 3 | 3 | 1 | 1 | 2 | 2 |
| Geometric | Mean | 21 | | 2 | 2 | 34 | 31 |
| | S.D. | 6 | | 2 | 2 | 4 | 6 |
| >100 µg/m³ | No. | 3 | 0 | 0 | 0 | 2 | 17 |
| | % | 15 | | | | 15 | 30 |
| >500 µg/m³ | No. | 1 | 0 | 0 | 0 | 2 | 4 |
| | % | 5 | | | | 15 | 7 |

3.3.2 The levels of exposure to rosin in the canning industry were negligible with an average exposure of only 2 µg/m³. The levels in the manufacturing industry were higher with an average of 21 µg/m³. There was no significant difference in the levels of exposure between the four different factories selected in this industry. This was also the case for the factories in the canning industry.

3.3.3 There was no significant difference between the exposure levels of males and females in the soldering industry, with the average exposure for both sexes combined being 31 µg/m³. There was, however, a significant difference between the exposure levels of the different factories. Looking at the data for each of the factories separately (table 9), factory 19 had by far the highest average exposure at 215.4 µg/m³. Two factories had average exposures between 50 and 100 µg/m³: factory 18 (62.5 µg/m³) and factory 27 (90.1 µg/m³). It was not possible to split the exposures in this industry by job categories, since the a priori job classifications did not fit the actual activities of the workers. It was clear, however, from the job descriptions of the workers that the overwhelming majority were involved at some time in the day in some form of soldering.

### 3.4 Questionnaire and Exposure Data

3.4.1 A match was made of those workers who filled in the questionnaire and those who had exposure levels measured. An exact match was defined as a worker who matched exactly on the following variables:

Surname
1st Initial
Factory Number

3.4.2 This produced only one duplicate match, and these two workers were excluded from the analysis. In all subsequent analyses where symptoms and exposure are linked, all those exposed workers who did not have an exposure sample taken were excluded. All control workers were included.

**Short-term Samples**

3.4.3 Short term peak exposures were recorded in the case of 12 workers in the manufacturing industry and 7 in the soldering industry. Of the males in the manufacturing industry, peak exposures ranging from 200.7 $\mu g/m^3$ to 3,753.4 $\mu g/m^3$ were recorded, with one recording being below the detectable limit (BDL). The following table lists the levels of exposure recorded for these workers, the duration of the sample taken, and the number of all symptoms and respiratory symptoms recorded:

| Level of Exposure ($\mu g/m^3$) | Duration of Exposure (mins) | Number of symptoms | Number of respiratory symptoms |
|---|---|---|---|
| BDL | 20 | not matched | not matched |
| 201 | 130 | 0 | 0 |
| 233 | 131 | 1 | 0 |
| 651 | 105 | not matched | not matched |
| 810 | 61 | 3 | 1 |
| 835 | 54 | 0 | 0 |
| 1,268 | 46 | 1 | 0 |
| 1,461 | 51 | 3 | 2 |
| 2,021 | 46 | 1 | 0 |
| 2,813 | 48 | 0 | 0 |
| 3,704 | 20 | 3 | 2 |
| 3,753 | 27 | 1 | 0 |

3.4.4 Of these exposures, all but 1 were above 100 $\mu g/m^3$, nine (75%) were above 500 $\mu g/m^3$ and six (50%) were above 1,000 $\mu g/m^3$. There is no significant correlation between the number of symptoms and the level of exposure.

3.4.5 The corresponding table for workers in the soldering industry is shown below:

| Level of Exposure ($\mu g/m^3$) | Duration of Exposure (mins) | Exposure Group | Number of symptoms | Number of respiratory symptoms |
|---|---|---|---|---|
| BDL | 5 | 1 | not matched | not matched |
| BDL | 10 | 1 | 2 | 2 |
| BDL | 14 | 1 | 0 | 0 |
| BDL | 13 | 1 | 0 | 0 |
| 33 | 19 | 2 | 1 | 1 |
| 70 | 22 | 3 | 1 | 1 |
| 83 | 6 | 1 | 0 | 0 |

3.4.6 The exposure levels for workers in this industry are considerably lower than those in the manufacturing industry, with all samples being below 100 $\mu g/m^3$. There is clearly no significant correlation between number of symptoms and level of exposure for this industry, in part due to the small numbers available for analysis.

3.4.7 The reason for the higher short term samples in the manufacturing industry is likely to be a reflection of the type of exposure received. There is more likely to be short, high exposures in the manufacturing industry, compared to the soldering industry where exposures are more consistent over time.

**Long-term Samples**

3.4.8 Further analysis was performed on the workers in the soldering industry only, with particular reference to the females. Table 10 lists the number of workers reporting occupational symptoms split into three exposure groupings based on the recorded 8 hour TWA. There is a clear upward trend, both for the presence of at least one respiratory symptom and for at least one symptom, in the numbers of symptoms as the level of exposure increases. This is particularly true for the females, with significant increases in the levels of symptoms for both symptom categories as the amount of exposure increases (p-value $< 0.05$ in test for linear trend). Amongst the females, the odds ratios become significant for at least one symptom when the exposure exceeds 50 $\mu g/m^3$ and for at least one respiratory symptom when the exposure exceeds 100 $\mu g/m^3$. This means that, for those workers with exposures above these levels, the percentages of workers reporting symptoms become significantly higher than those for the control workers.

3.4.9 For males, although there also appears to be a significant increase in the percentage of workers with at least one respiratory symptom as the level of exposure increases, the numbers involved are small, making interpretation of the results difficult. There is no significant increase amongst the males for the presence of at least one symptom.

3.4.10 For the sexes combined, the odds ratios become significant for both symptom categories when the exposure exceeds 50 $\mu g/m^3$. This seems to indicate that a control level of 50 $\mu g/m^3$ would be the most appropriate for workers in the soldering industry.

3.4.11 It should be noted, however, that the numbers involved make controlling for age and smoking status impractical, and also that there is a difference in the profile of symptoms amongst the subset of male solderers who had their exposure level recorded, compared to that for all the male solderers who completed the health questionnaire.

3.4.12 Table 11 examines the prevalence of both respiratory and all symptoms split by the type of respiratory protective equipment used by the worker. There appears to be a consistent overall reduction in the prevalence of symptoms when either local exhaust ventilation (LEV) or on-gun tip extraction is used. There is a significant reduction in the percentage of females reporting at least one respiratory symptom who use LEV. This results is reproduced when the two sexes are combined. This significant reduction is neither manifest amongst male solderers, nor for the reporting of at least one symptom. The numbers involved here are, however, small and the results should be treated with caution.

## 4) Conclusions

4.1 There is evidence that exposure to rosin fumes increased the prevalence of at least one of the six symptoms amongst females in the soldering industry. This was not, however, the case for the respiratory symptoms, nor was it the case for the male workers. There is, however, no obvious explanation for the differing results between males and females.

4.2 There is evidence that higher exposure levels increase the prevalence of symptoms amongst female workers in the soldering industry and some evidence that the same is true for male solderers. For both sexes combined, there is a significant increase in the prevalence of symptoms, as compared to the control workers, when the exposure levels exceed 50 $\mu g/m^3$. This would appear to be the most sensible exposure level for setting a control limit.

4.3 There is some evidence to suggest that the use of ventilation equipment. and LEV in particular, reduces the prevalence of symptoms.

4.4 The length of exposure to rosin fume does not appear to affect the prevalence of job-related symptoms.

4.5 The inability to uniquely categorise the job activities in the three industries would have created a weakness in the linking of the exposure data to the number of symptoms had the workers not been able to be matched individually. This matching of individual's questionnaire and sampling results is strongly recommended for future TDSs.

## 5) References

1) Burge, P S, Perks, W, O'Brien, I M, Hawkins, R, Green, M (1979)
Occupational Asthma in an Electronics Factory
Thorax, **34**, 13-18

2) Industrial Injuries Scheme
Department of Social Security

3) The Statistical System for Generalised Linear Interactive Modelling

4) StatXact-Turbo, Statistical Software for Exact Non-parametric Inference
CYTEL Software Corporation

5) LogXact-Turbo, Logistic Regression Featuring Exact Methods
CYTEL Software Corporation

# APPENDIX 2

# HEALTH QUESTIONNAIRE

Factory code

FOR OFFICE USE ONLY

HSE
Health & Safety Executive

Survey No.

FOR OFFICE USE ONLY

# THE EXPOSURE TO ROSIN FUMES OF WORKERS IN THE SOLDERING, ROSIN MANUFACTURE AND CANNING INDUSTRIES.

Dear Sir/Madam

With the co-operation of your employer we are conducting a survey to find out the pattern and extent of exposure to colophony fumes, together with prevalence of respiratory impairment(s), if any; suffered at work and away from work.

We would like you to complete this questionnaire about your health. All answers will be treated as **strictly confidential** and individual answers will not be made known to anyone other than the survey team.

The more questionnaires that are completed, the greater will be the accuracy and usefulness of the findings, the better to help us improve health and safety at work.

Thank you for your help.

Dr Richard Elliott

---

## HOW TO ANSWER THE QUESTIONNAIRE

Please complete the questionnaire by answering ALL questions as fully as possible. Some of the questions require a written answer, for others you need only tick a box. ☐

---

REC 01

## PERSONAL DETAILS

Today's date — Day Month Year ☐☐☐☐☐☐

Sex — Male ☐ Female ☐

Surname (*please write in capitals*) .....

Initials .....

Date of birth — Day Month Year ☐☐☐☐☐☐

---

REC 02

## HEALTH DETAILS (*Coughing*)

Please answer by using the tick boxes ☐
*-one tick for each question.*
Some questions require a written answer - please see job activity card for guidance.

1. Do you cough at all on most days for as much as three months in the year? Yes ☐ No ☐

2. Do you bring up phelgm from your chest on most days for as much as three months in the year? Yes ☐ No ☐

3. Do you suffer from attacks of coughing? Yes ☐ No ☐

   *(If answered 'No' please go to Q7)*

4. Are your attacks of coughing more likely to occur when you are on holiday for a week or more? Yes ☐ No ☐

   *(If answered 'Yes' please go to Q6)*

5. Are your attacks of coughing less likely to occur when you are on holiday for a week or more? Yes ☐ No ☐

6. Do your attacks of coughing occur when you do (or have done) anything in particular? Yes ☐ No ☐

If yes, please specify:..... FOR OFFICE USE ONLY ☐ AC
*(see job activity card for guidance)*

7. Does your chest ever sound wheezy or whistly? Yes ☐ No ☐

8. Do you have tightness in the chest or shortness of breath? Yes ☐ No ☐

*(If you have answered 'No' to Questions 7 & 8 please go to Q12)*

9. Is it (are they) worse than normal when you are on holiday for a week or more? Yes ☐ No ☐

*(If answered 'Yes' please go to Q11)*

10. Is it (are they) better than normal when you are on holiday for a week or more? Yes ☐ No ☐

11. Is it (are they) worse when you do (or have done) anything in particular? Yes ☐ No ☐

If yes, please specify:..... FOR OFFICE USE ONLY ☐ AC

---

REC 03

## HEALTH DETAILS *(Nose irritancy)*

Please answer by using the tick boxes ☐
*-one tick for each question.*
Some questions require a written answer - please see job activity card for guidance.

12. Do you ever have an itchy nose with sneezing and stuffiness? Yes ☐ No ☐

*(If answered 'No' please go to Q16).*

13. Is it (or are they) better than normal when you are on holiday for a week or more? Yes ☐ No ☐

*(If answered 'Yes' please go to Q15)*

14. Is it (or are they) worse than normal when you are on holiday for a week or more? Yes ☐ No ☐

15. Is it (or are they) worse when you do (or have done) anything in particular? Yes ☐ No ☐

If yes, please specify:..... FOR OFFICE USE ONLY ☐ AC

16. Does anything in particular make you sneeze, when you don't have a cold? Yes ☐ No ☐

*(If answered 'No' please go to Q18)*

17. If yes, please specify:..... FOR OFFICE USE ONLY ☐ AC

---

REC 04

## HEALTH DETAILS (*Eye irritancy*)

Please answer by using the tick boxes ☐
*-one tick for each question.*
Some questions require a written answer - please see job activity card for guidance.

18. Do you ever have itchy red eyes? Yes ☐ No ☐

*(If answered 'No' please go to Q22)*

19. Are they better than normal when you are on holiday for a week or more? Yes ☐ No ☐

*(If answered 'Yes' please go to Q21)*

20. Are they worse than normal when you are on holiday for a week or more? Yes ☐ No ☐

21. Are they worse when you do (or have done) anything in particular? Yes ☐ No ☐

If yes, please specify:..... FOR OFFICE USE ONLY ☐ AC

---

## OCCUPATIONAL HISTORY

Please answer by using the tick boxes ☐
*-one tick for each question.*
Some questions require a written answer - please see job activity card for guidance.

30. How long have you worked for your current employer? Years ☐☐ Months ☐☐

31. After reading the attached job activity list for this employment - please indicate the *type of job* you are now doing. (One job only please)

Job type: ..... FOR OFFICE USE ONLY ☐ JC

32. How long have you done this job? Years ☐☐ Months ☐☐

33. Have you done any other jobs for this company? Yes ☐ No ☐

34. If yes, please record the job titles for up to *two* further jobs.

*(Please state most recent jobs (excluding present job) first)*

Job No.1 :..... FOR OFFICE USE ONLY ☐ JC

Job No.2 :..... FOR OFFICE USE ONLY ☐ JC

35. How long did you spend in this/these job(s)?

Job 1: Years ☐☐ Months ☐☐

Job 2: Years ☐☐ Months ☐☐

*(The following questions refer to your previous employment before starting with this firm).*

36. Have you ever suffered from any chest illness due to a previous job? *(Not with your current employer)* Yes ☐ No ☐

*(If answered 'NO' please go to Q39)*

FOR OFFICE USE ONLY ☐

37. What was that job? :.....

JC

38. What was your chest illness? :.....

---

REC 08

## HEALTH - CHEST ILLNESSES

Please answer by using the tick boxes ☐
*-one tick for each question.*
Some questions require a written answer - please be brief.

39. During the past three years how many times (if any) have you missed work due to a chest related illness? ☐ Times

40. Did your doctor say your illness was one / or more of those listed below?

| | | | | | |
|---|---|---|---|---|---|
| Asthma | Yes ☐ | No ☐ | Number of times | ☐ |
| Bronchitis | Yes ☐ | No ☐ | Number of times | ☐ |
| Cold | Yes ☐ | No ☐ | Number of times | ☐ |
| Influenza | Yes ☐ | No ☐ | Number of times | ☐ |
| Other (please specify) :..... | | | Number of times | ☐ |

---

Thank you for your help.

# APPENDIX 3

# JOB /ACTIVITY CODES

(M1) (Factories 10,11,12)

# Job / Activity card

## Rosin Manufacture

| | | | FOR OFFICE USE ONLY Activity code | Factory |
|---|---|---|---|---|
| **Job:** | Process Operator 1 | 1 | | {10,12 |
| **Activity:** | charging of rosin to reaction vessel/storage tank | | (A) | |
| | charging of other chemicals | | (B) | |
| | taking samples | | (C) | |
| | ..... | | | |
| **Job:** | Process Operator 2 | 2 | | {11} |
| **Activity:** | cutting of drums | | (D) | |
| | manual breaking up of rosin | | (E) | |
| | charging to reaction vessel | | (F) | |
| | charging of other chemicals | | (G) | |
| | ..... | | | |
| **Job:** | Process Operator 3 | 3 | | {10, 11,1 |
| **Activity:** | discharge of products to tankers | | (H) | |
| | discharge of product to drums | | (I) | |
| | sealing drums | | (J) | |
| | ..... | | | |
| **Job:** | Process Operator 4 (modified rosin) | 4 | | {10 |
| **Activity:** | work associated with droplet former | | (K) | |
| | bagging of finished modified rosin | | (L) | |
| | cleaning of filling area | | (M) | |
| | ..... | | | |
| **Job:** | Quality Control | 5 | | |
| **Activity:** | performing laboratory analysis on samples | | (N) | |

(M1) continued

FOR OFFICE USE ONLY

| | | | Activity code | Factory |
|---|---|---|---|---|
| **Job:** | Supervisor | 6 | (O) | |
| **Activity:** | Supervision of rosin plant<br>Supervision of modified rosin plant<br>Supervision of discharge / drumming areas | | (P) | |
| | ..... | | | |
| **Job:** | Maintenance | 7 | (Q) | |
| **Activity:** | Maintenance | | | |
| | ..... | | | |
| **Activity:** | Not work related | | (Z) | |

# Job / Activity card

## Rosin-cored solder Manufacture

FOR OFFICE USE ONLY

| | | | Activity code | Facto |
|---|---|---|---|---|
| **Job:** | Rosin Process Operator | 1 | | |
| **Activity:** | Breaking up of rosin | | (A) | |
| | Adding activators | | (B) | |
| | Discharge to drums | | (C) | |
| | ..... | | | |
| **Job:** | Extruder | 2 | | |
| **Activity:** | Breaking up of flux | | (D) | |
| | Loading of flux hopper | | (E) | |
| | Extrusion of flux | | (F) | |
| | ..... | | | |
| **Job:** | Drawing operator | 3 | | |
| **Activity:** | Using bull-blocking machine | | (G) | |
| | Drawing wine | | (H) | |
| | Soldering ends of coil | | (I) | |
| | ..... | | | |
| **Job:** | Winding and packing | 4 | | |
| **Activity:** | Winding solder wire to reels | | (J) | |
| | Packing of reels | | (K) | |
| | ..... | | | |
| **Job:** | Inspection and QC | 5 | | |
| **Activity:** | Inspection of solder wire | | (L) | |
| | QC of rosin and flux | | (M) | |
| | ..... | | | |

(M2) continued.

FOR OFFICE USE ONLY

Activity code Factory

| | | | |
|---|---|---|---|
| **Job:** | Supervisor | 6 | |
| **Activity:** | Supervision of solder flux area | | (N) |
| | Supervision of extrusion area | | (O) |
| | Supervision of block/drawing area | | (P) |
| | Supervision of Winding /Inspection area | | (Q) |
| | ..... | | |
| **Job:** | Maintenance | 7 | |
| **Activity:** | Maintenance of machines | | (R) |
| | ..... | | |
| **Activity:** | Not work related | | (Z) |

(C) (Factories 15,16,17)

# Job / Activity card

FOR OFFICE USE ONLY

Activity code | Factory

## Canning Industry

| | | | |
|---|---|---|---|
| **Job:** | Labeller | 1 | |
| **Activity:** | Filling glue pot on labelling machine | | (A) |
| | Sorting out problems on the labelling machine | | (B) |
| | Cleaning the labelling machine | | (C) |
| | ..... | | |
| **Job:** | Packer | 2 | |
| **Activity:** | Load / make trays | | (D) |
| | Fill glue pot | | (E) |
| | Checking progress of cans on line | | (F) |
| | Checking progress of packing and stacking | | (G) |
| | Cleaning the machine | | (H) |
| | ..... | | |
| **Job:** | Supervisor | 3 | |
| **Activity:** | Supervising work of labelling area | | (I) |
| | ..... | | |
| **Job:** | Maintenance | 4 | |
| **Activity:** | Maintenance of machines in labelling area | | (J) |
| | ..... | | |
| **Activity:** | Not work related | | (Z) |

(S) (Factories 18-21)

7

# Job / Activity card

FOR OFFICE USE ONLY
Activity code | Factory

## Soldering

| | | | |
|---|---|---|---|
| **Job:** | Solderer | 1 | |
| **Activity:** | Manual soldering | | (A) |
| | Automatic soldering | | (B) |
| | Semi-automatic soldering | | (C) |
| | Tinning | | (D) |
| | Desoldering | | (E) |
| | ..... | | |
| **Job:** | Assembler | 2 | |
| **Activity:** | Preparing components for soldering | | (F) |
| | Assembling components after soldering | | (G) |
| | Testing | | (H) |
| | Inspection | | (I) |
| | Occasional soldering | | (J) |
| | ..... | | |
| **Job:** | Supervisor | 3 | |
| **Activity:** | Supervising work in soldering area | | (K) |
| | ..... | | |
| **Job:** | Maintenance | 4 | |
| **Activity:** | Maintenance of equipment | | (L) |
| | ..... | | |
| **Activity:** | Not work related | | (Z) |

Job: Quality Control 5

# APPENDIX 4

# HSL REPORT

Project Report

HEALTH AND SAFETY EXECUTIVE
HEALTH AND SAFETY LABORATORY
Broad Lane, Sheffield S3 7HQ

# COLOPHONY FUME TECHNICAL DEVELOPMENT SURVEY - REVIEW OF RESULTS

by
I Pengelly
Complex Substances and Fume Section

IR/L/SP/94/05
Project No. S20.965

Issue authorised by
Dr J Groves
July 1994

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## SUMMARY

This report presents a summary of the results generated from a technical development survey for colophony (also known as rosin). The survey involved taking samples at 16 sites covering three industries using rosin based products - namely rosin manufacture, hot melt glue users and soldering.

Samples of both the particulate and volatile fractions of the fume were collected during the survey and analysed by gas chromatography. The particulate samples were collected onto membrane filters and analysed for Total Resin Acid (TRA) content by gas chromatography. The volatile samples were collected onto charcoal tubes and analysed for volatile terpenes, also by gas chromatography. In addition, a number of bulk rosin, glue and solder samples were analysed for resin acid/terpene composition.

The samples were further divided into personal and static samples. Personal samples were taken attached to either the lapel (rosin manufacturers and hot melt glue users) or to the breathing zone (solderers) of individual employees. Static samples were taken in fixed locations throughout the work area.

Specific Achievements

1. Summary of the results obtained from the colophony TDS for both Total Resin Acid (TRA) in the particulate fraction and volatile terpenes in the vapour phase is presented.

2. Examination of differences in fume composition in samples collected from the types of industry visited (rosin manufacture, hot melt glue users and soldering).

## CONTENTS

## 1. INTRODUCTION

A technical development survey (TDS) for colophony (rosin) was carried out in late 1993/early 1994. Sampling was carried out by FCG scientific staff at Leeds, Birmingham, Luton, Manchester and East Grinstead in the following three groups of industries:-

- Rosin Manufacture
- Processes using Hot Melt Glues (particularly Canning)
- Soldering

The samples taken consisted of membrane filters collecting particulate[1,2], charcoal tubes collecting volatiles[1,3] and a small number of bulk rosin/glue/solder samples. Particulate samples were collected using both portable low volume pumps and mains-driven high volume sampling pumps. The samples were subsequently sent to Complex Substances & Fume Section for analysis, the particulate fraction for resin acid content and the volatile fraction for mono- and sesquiterpenes and other volatile hydrocarbons[1-3].

A total of 330 samples of all types were collected and analysed during the TDS. The results are summarised in the following Sections, throughout which the abbreviations shown below have been used.

| | | |
|---|---|---|
| LVF-13S | = | Low volume static sample on 13 mm membrane filter |
| LVF-13P | = | Low volume personal sample on 13 mm membrane filter |
| LVF-25S | = | Low volume static sample on 25 mm membrane filter |
| LVF-25P | = | Low volume personal sample on 25 mm membrane filter |
| LVT-S | = | Low volume static sample on charcoal tube |
| LVT-P | = | Low volume personal sample on charcoal tube |
| HVF-37S | = | High volume static sample on 37 mm filter |
| HVF-47S | = | High volume static sample on 47 mm filter |
| HVF-60S | = | High volume static sample on 60 mm filter |
| TRA | = | Total Resin Acid |
| PIM | = | Pimaric Acid |
| SAN | = | Sandaracopimaric Acid |
| ISO | = | Isopimaric Acid |
| PAL | = | Palustric Acid |
| DHA | = | Dehydroabietic Acid |
| ABI | = | Abietic Acid |
| NEO | = | Neoabietic Acid |

## 2. ROSIN MANUFACTURERS

### 2.1 Factory 14

Worksheet OH329/93

6 samples:- 2 × LVF-25P
1 × LVF-25S
2 × HVF-47S
1 × Bulk Rosin

As can be seen in Table 1, filter loadings were in four of the five air samples were extremely low. Sample compositions for these four samples are therefore only very rough estimates. The main difference between the bulk sample of rosin received and the one resin acid composition on the one remaining air sample (LS/20828/93) is that the bulk sample contains predominantly abietic acid, whereas the air sample contains predominantly dehydroabietic acid.

**TABLE 1: Summary of Results at Factory 14**

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| LS/20828/93 | LVF-25P | 128 | 423 | 52% Dha, 5% Iso, 5% Pal, 4% Abi, 1% Pim, 33% Other |
| LS/20929/93 | LVF-25S | 240 | 8 | Too low to accurately assess - appears mainly Dha |
| LS/20930/93 | LVF-25P | 30 | 62 | Too low to accurately assess - appears mainly Dha |
| LS/20933/93 | HVF-47S | 8550 | 1.2 | 27% Dha, 25% Pim, 21% Iso, 9% Abi, 18% Other |
| LS/20936/93 | HVF-47S | 7920 | 0.9 | 36% Dha, 23% Iso, 22% Abi, 10% Pim, 9% Other |
| LS/20941/93 | Bulk Rosin | **** | **** | 36% Abi, 18% Iso, 8% Dha, 7% Pal, 4% Pim, 4% San, 3% Neo |

### 2.2 Factory 11

Worksheets OH349/93 & OH358/93

54 samples:- 25 × LVF-25P
2 × LVF-25S
24 × LVT-P
2 × LVT-S
1 × Bulk Rosin

Table 2 shows the results of the charcoal tubes samples. The main components present were α-pinene, β-pinene and a group of sesquiterpenes. Airborne levels of the three compounds were extremely low with the combined level of α-pinene and β-pinene rising above 2 µg/m³ in only 1 out of the 26 samples. Sesquiterpene levels were also low, with total concentration rising above 2 µg/m³ in 4 of the 26 samples.

## TABLE 2: Summary of Results at Factory 11 (Volatiles)

| Sample Number | Sample Type | Sample Volume (l) | α-Pinene (µg/m³) | β-Pinene (µg/m³) | Limonene (µg/m³) | Sesquiterpenes (µg/m³) |
|---|---|---|---|---|---|---|
| NE/31183/93 | LVT-P | 88 | N/D | N/D | - | 1.2 |
| NE/31184/93 | LVT-P | 29 | N/D | N/D | - | N/D |
| NE/31185/93 | LVT-P | 150 | 0.8 | 0.6 | - | 1.9 |
| NE/31186/93 | LVT-P | 190 | 0.4 | 0.3 | - | 1.0 |
| NE/31187/93 | LVT-P | 189 | N/D | 0.2 | - | 0.5 |
| NE/31188/93 | LVT-P | 153 | N/D | N/D | - | 0.7 |
| NE/31189/93 | LVT-P | 144 | N/D | N/D | - | N/D |
| NE/31190/93 | LVT-P | 164 | N/D | N/D | - | N/D |
| NE/31191/93 | LVT-P | 155 | N/D | N/D | - | N/D |
| NE/31192/93 | LVT-P | 152 | 0.5 | 0.9 | - | 3.8 |
| NE/31193/93 | LVT-P | 158 | N/D | N/D | - | N/D |
| NE/31194/93 | LVT-P | 159 | 0.3 | 0.4 | - | 1.3 |
| NE/31195/93 | LVT-P | 197 | 0.4 | 0.4 | - | 0.6 |
| NE/31196/93 | LVT-P | 180 | 0.4 | 0.5 | - | 1.3 |
| NE/31197/93 | LVT-P | 77 - 192 | N/D | N/D | - | N/D |
| NE/31198/93 | LVT-P | 140 | N/D | N/D | - | 0.6 |
| NE/31199/93 | LVT-P | 148 | N/D | N/D | - | N/D |
| NE/31200/93 | LVT-P | 89 - 162 | N/D | N/D | - | 0.4 - 0.7 |
| NE/31201/93 | LVT-P | 28 | N/D | N/D | - | 3.3 |
| NE/31202/93 | LVT-P | 24 | N/D | N/D | - | N/D |
| NE/31203/93 | LVT-P | 194 | N/D | 0.4 | - | 0.4 |
| NE/31204/93 | LVT-S | 167 | N/D | N/D | - | N/D |
| NE/31205/93 | LVT-S | 153 | 0.3 | 0.6 | - | 0.8 |
| NE/31206/93 | LVT-P | 147 | 0.3 | 1.0 | - | 7.7 |
| NE/31207/93 | LVT-P | 145 | 4.5 | 0.9 | - | 5.3 |
| NE/31208/93 | LVT-P | 138 | 1.0 | 0.5 | - | 3.1 |

Table 3 shows the results of the filter samples for airborne resin acid levels, as well as the resin acid composition of the bulk rosin (NCY Rosin) sample. Of the 27 air samples, 8 gave TRA concentrations below the calculated detection limit, 7 gave levels between the detection limit and 50 µg/m³, 5 between 50 and 100 µg/m³, 5 between 100 and 250 µg/m³ and the remaining 2 levels of over 500 µg/m³.

The two highest TRA concentrations over 500 µg/m³ (NE/31159/93 and NE/31170/93) both occured on a worker whose job involved filling a road tanker with liquid rosin via a heated overhead pipeline, although a third sample taken whilst he was carrying out the same task gave a much lower reading of around 60 µg/m³ (NE/31155/93). The group of samples showing the next highest TRA concentrations of between 100 and 250 µg/m³

were found on personnel working in the Modified Rosin Production (MRP) area (typically bagging rosin pellets or capping drums). Most of the "*Not Detected*" and lower TRA concentrations were taken from personnel working in the Tall Oil Production (TOP) area.

## TABLE 3: Summary of Results at Factory 11 (Resin Acids)

| Sample Number | Sample Type | Sample Volume (l) | TRA ($\mu g/m^3$) | Sample Composition |
|---|---|---|---|---|
| NE/31155/93 | LVF-25P | 88 | 58 | 36% Dha, 22% Abi, 10% Neo, 11% Iso, 8% Pal, 7% San, 6% Pim |
| NE/31156/93 | LVF-25P | 29 | N/D | **** |
| NE/31157/93 | LVF-25P | 150 | N/D | **** |
| NE/31158/93 | LVF-25P | 190 | 33 | 41% Dha, 12% Iso, 8% Abi, 5% Neo, 5% Pal, 4% Pim, 25% Other |
| NE/31159/93 | LVF-25P | 189 | 849 | 30% Dha, 29% Abi, 12% Iso, 10% Pal, 6% Pim, 3% San, 2% Neo, 8% Other |
| NE/31160/93 | LVF-25P | 153 | 121 | 33% Dha, 24% Abi, 12% Iso, 7% Pal, 7% Pim, 3% San, 2% Neo, 12% Other |
| NE/31161/93 | LVF-25P | 144 | 141 | 52% Dha, 12% Abi, 5% Iso, 4% Pal, 2% Pim, 2% Neo, 1% San, 22% Other |
| NE/31162/93 | LVF-25P | 164 | 161 | 49% Dha, 16% Abi, 7% Pal, 5% Iso, 2% San, 2% Pim, 1% Neo, 18% Other |
| NE/31163/93 | LVF-25P | 155 | 51 | 54% Dha, 16% Abi, 8% Pal, 5% Iso, 17% Other |
| NE/31164/93 | LVF-25P | 152 | 8 | Too low to accurately assess - appears to be mainly Dha |
| NE/31165/93 | LVF-25P | 158 | N/D | **** |
| NE/31166/93 | LVF-25P | 3 | N/D | **** |
| NE/31167/93 | LVF-25P | 159 | 8 | Too low to accurately assess - appears to be mainly Dha |
| NE/31168/93 | LVF-25P | 197 | 6 | Too low to accurately assess - appears to be mainly Dha |
| NE/31169/93 | LVF-25P | 180 | N/D | **** |
| NE/31170/93 | LVF-25P | 77 - 192 | 407 - 1015 | 32% Dha, 30% Abi, 10% Iso, 9% Pal, 5% Pim, 3% San, 2% Neo, 9% Other |
| NE/31171/93 | LVF-25P | 140 | 20 | 49% Dha, 12% Iso, 11% Abi, 7% Pal, 21% Other |
| NE/31172/93 | LVF-25P | 148 | 10 | Too low to accurately assess - appears to be mainly Dha |
| NE/31173/93 | LVF-25P | 89 - 162 | 48 - 88 | 39% Dha, 16% Iso, 13% Abi, 8% Pim, 4% Neo, 4% Pal, 16% Other |
| NE/31174/93 | LVF-25P | 28 | N/D | **** |
| NE/31175/93 | LVF-25P | 24 | 53 | Too low to accurately assess - appears to be mainly Dha |
| NE/31176/93 | LVF-25P | 194 | 169 | 47% Dha, 17% Abi, 7% Pal, 6% Iso, 2% Pim, 2% San, 1% Neo, 18% Other |
| NE/31177/93 | LVF-25S | 167 | 135 | 48% Dha, 16% Abi, 6% Pal, 6% Iso, 2% Pim, 2% San, 2% Neo, 18% Other |
| NE/31178/93 | LVF-25S | 153 | 71 | 35% Dha, 25% Abi, 9% Iso, 8% Pal, 4% San, 2% Pim, 2% Neo, 15% Other |
| NE/31179/93 | LVF-25P | 147 | 12 | Too low to accurately assess - appears to be mainly Dha |
| NE/31180/93 | LVF-25P | 145 | N/D | **** |
| NE/31181/93 | LVF-25P | 138 | N/D | **** |
| NE/31210/93 | Bulk Rosin | **** | **** | 40% Abi, 28% Dha, 13% Pal, 7% Iso, 5% Neo, 3% Pim, 1% San, 3% Other |

The NCY bulk rosin sample gave a resin acid composition of 40% ABI, 28% DHA, 13% PAL, 7% ISO, 5% NEO, 3% PIM, 1% SAN and 3% others. This composition shows some

significant differences when compared with those observed in the 19 air samples with the resin acid compositions with TRA levels above the detection limit. In particular all the air samples show higher proportions of DHA and lower proportions of ABI suggesting the occurance of some degradation/oxidation of the rosin during processing. Typically the resin acid compositions in the 19 air samples falls into one of the following 3 groups:-

a) Samples in which the TRA levels were too low to accurately assess the resin acid composition but which appeared to be composed largely of DHA.

b) Samples in which the proportions of DHA and ABI were fairly similar (the DHA typically being between 30 and 35% and the ABI between 25 and 30%).

c) Samples in which the proportion of DHA is around 3 - 4 times that of ABI (the DHA typically being between 45 and 55% and the ABI between 12 and 18%).

The samples comprising group ***b*** were mainly from personnel involved in loading liquid rosin into tankers for transportation, although one sample (NE/31173/93) was from a static sample sample taken at the hot end of the pellet cooling conveyer in the MRP area. The samples comprising groups ***a*** and ***c*** were generally taken from personnel working in the TOP and other parts of the MRP areas. This observation suggests that for this particular factory, samples taken adjacent to areas of hot liquid rosin tend to show higher proportions of ABI than samples taken from elsewhere.

## 2.3 Factory 10

Worksheets OH350/93, OH351/93, OH359/93, OH360/93 & OH361/93

30 samples:- 10 × LVF-25P
5 × LVF-25S
8 × LVT-P
3 × LVT-S
4 × Bulk Rosin

Table 4 shows the results of the four main components (a-pinene, b-pinene, limonene and sesquiterpenes) found in the charcoal tubes samples. The results show airborne concentrations on the first day of the two day visit to be extremely low (NE/31227/93 - NE/31332/93), but results on the second day to be significantly higher (several hundred times higher on average in the case of α-pinene and the sesquiterpenes). There is no obvious reason for this in the type of job from which the samples were taken and indeed the TRA results (Table 5) show higher levels on Day 1 than on Day 2.

Table 5 shows the results of the filter samples for airborne resin acid levels, as well as the resin acid composition of the 4 bulk rosin samples. Of the 15 air samples, all gave gave TRA concentrations of over 200 µg/m³, with 10 of these being over 500 µg/m³, 6 being over 1000 µg/m³ and 3 being over 2500 µg/m³. Indeed, in the case of samples NE/31220/93 - NE/31223/93 which gave the highest readings, the values obtained are probably minimum values since some the sample tims received showed evidence of some of the collected particulate having fallen off the filters.

## TABLE 4: Summary of Results at Factory 10 (Volatiles)

| Sample Number | Sample Type | Sample Volume (l) | α-Pinene (µg/m³) | β-Pinene (µg/m³) | Limonene (µg/m³) | Sesquiterpenes (µg/m³) |
|---|---|---|---|---|---|---|
| NE/31227/93 | LVT-P | 36 | N/D | 0.8 | N/D | N/D |
| NE/31228/93 | LVT-P | 39 | N/D | 1.2 | N/D | N/D |
| NE/31229/93 | LVT-P | 27 | 5.1 | 4.0 | N/D | 24 |
| NE/31230/93 | LVT-P | 22 | 3.2 | 1.9 | N/D | 9.6 |
| NE/31231/93 | LVT-P | 139 | N/D | N/D | N/D | N/D |
| NE/31232/93 | LVT-P | 134 | 0.4 | 0.4 | N/D | 1.0 |
| NE/31247/93 | LVT-S | 50 | 390 | 80 | 31 | 4455 |
| NE/31248/93 | LVT-S | 49 | 256 | 51 | 9.0 | 2646 |
| NE/31249/93 | LVT-S | 54 | 70 | 25 | 4.0 | 817 |
| NE/31250/93 | LVT-P | 54 | 462 | 54 | 32 | 4817 |
| NE/31251/93 | LVT-P | 57 | 610 | 50 | 20 | 4973 |

## TABLE 5: Summary of Results at Factory 10 (Resin Acids)

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| NE/31212/93 | LVF-25P | 67 | 1461 | 34% Dha, 11% Pim, 6% Iso, 5% Abi, 3% Pal, 3% San, 2% Neo, 36% Other |
| NE/31213/93 | LVF-25P | 61 | 810 | 37% Dha, 12% Pim, 7% Iso, 5% Abi, 4% Pal, 3% San, 2% Neo, 30% Other |
| NE/31214/93 | LVF-25S | 64 | 335 | 35% Dha, 11% Pim, 8% Abi, 7% Iso, 5% Pal, 3% San, 31% Other |
| NE/31215/93 | LVF-25S | 61 | 325 | 35% Dha, 12% Pim, 7% Abi, 7% Iso, 4% Pal, 3% San, 32% Other |
| NE/31220/93 | LVF-25P | 36 | 2813 | 39% Abi, 16% Pal, 14% Neo, 12% Dha, 11% Pim, 4% Iso, 3% San, 1% Other |
| NE/31221/93 | LVF-25P | 39 | 2021 | 38% Abi, 15% Pal, 13% Dha, 13% Neo, 12% Pim, 4% Iso, 3% San, 2% Other |
| NE/31222/93 | LVF-25P | 27 | 3754 | 35% Abi, 22% Dha, 13% Pal, 11% Pim, 8% Neo, 4% Iso, 2% San, 5% Other |
| NE/31223/93 | LVF-25P | 22 | 3704 | 34% Abi, 22% Dha, 13% Pal, 12% Pim, 8% Neo, 3% Iso, 2% San, 6% Other |
| NE/31224/93 | LVF-25P | 139 | 201 | 33% Abi, 24% Dha, 12% Pal, 9% Pim, 5% Neo, 4% Iso, 1% San, 12% Other |
| NE/31225/93 | LVF-25P | 134 | 233 | 33% Abi, 24% Dha, 11% Pal, 8% Pim, 6% Neo, 5% Iso, 1% San, 12% Other |
| NE/31241/93 | LVF-25S | 50 | 835 | 35% Dha, 11% Pim, 6% Iso, 4% Abi, 4% Pal, 2% Neo, 1% San, 37% Other |
| NE/31242/93 | LVF-25S | 49 | 530 | 38% Dha, 11% Pim, 7% Iso, 6% Abi, 5% Pal, 2% San, 2% Neo, 29% Other |
| NE/31243/93 | LVF-25S | 54 | 201 | 39% Dha, 12% Pim, 8% Iso, 5% Abi, 5% Pal, 3% San, 1% Neo, 27% Other |
| NE/31244/93 | LVF-25P | 54 | 1082 | 39% Dha, 10% Pim, 7% Iso, 6% Abi, 5% Pal, 2% Neo, 1% San, 30% Other |
| NE/31245/93 | LVF-25P | 57 | 1268 | 35% Dha, 9% Pim, 6% Iso, 4% Pal, 3% Abi, 3% Neo, 1% San, 39% Other |
| NE/31217/93 | Bulk Rosin | **** | **** | 35% Abi, 25% Dha, 11% Pal, 6% Pim, 5% Iso, 5% Neo, 1% San, 12% Other |
| NE/31234/93 | Bulk Rosin | **** | **** | 48% Abi, 20% Pal, 16% Neo, 8% Pim, 5% Dha, 2% San, 1% Iso |
| NE/31235/93 | Bulk Rosin | **** | **** | 36% Abi, 24% Dha, 11% Pal, 6% Pim, 6% Neo, 1% San, 16% Other |
| NE/31253/93 | Bulk Rosin | **** | **** | 34% Abi, 27% Dha, 11% Pal, 6% Pim, 5% Neo, 4% Iso, 2% San, 11% Other |

As mentioned above it was noted that samples taken on Day 2 which indicated much higher concetrations of volatile terpenes did not coincide with those samples giving the

highest airborne TRA levels. On the contrary, samples NE/31220/93 - NE/31223/93 which contained the highest levels of TRA, had very low levels of terpenes (samples NE/31227/93 - NE/31232/93).

Three of the bulk rosin samples, namely NE/31217/93 (the rosin being bagged on Day 1), NE/31235/93 (rosin residue obtained from the tank during cleaning) and NE/31253/93 (the rosin being bagged on Day 2) showed quite similar resin acid compositions with around 35% ABI, 25% DHA, 11% PAL, 6% PIM, 5% ISO, 5% NEO, 2% SAN and 11% others. The other sample (NE/31234/93 - the rosin being loaded into the melter) had a somewhat different composition with significantly increased levels of PAL and NEO and significantly decreased levels of DHA and ISO (48% ABI, 20% PAL, 16% NEO, 8% PIM, 5% DHA, 2% SAN and 1% ISO). The difference would appear to result from the fact the sample with the low DHA content (NE/31234/93) comes from a sample of unprocessed rosin, whereas the other three samples have come from samples of rosin after processing.

This composition shows some significant differences when compared with those observed in the 15 air samples. In particular all the air samples show higher proportions of DHA and lower proportions of ABI suggesting the occurance of some degradation/oxidation of the rosin during processing. Typically the resin acid compositions in the air samples taken fall into one of the following 3 groups:-

a) Samples in which ABI makes up about 40% of the TRA collected, with PAL, NEO, DHA and PIM making up a further 10 - 15% each. The composition of these samples most closely resembles that of the bulk sample obtained from unprocessed rosin (NE/31234/93).

b) Samples in which ABI makes up about one third of the TRA collected, DHA around 23%, and NEO, PAL and PIM a further 8 - 13% each. The composition of these samples most closely resembles that of the three bulk samples obtained from processed rosin (NE/31217/93, NE/31235/93 and NE/31253/93).

c) Samples in which DHA is the main resin acid present, making up some 35 - 40% of the TRA collected, with the proportion of PIM around 10 - 12% and ISO, ABI and PAL at 3 - 7% each. In these samples a significant proportion of the TRA collected (*ca.* 30% is made up of other minor resin acids).

The samples comprising group ***a*** were the two heavily loaded samples from personnel loading raw rosin into the melter. Samples in group ***b*** were from four personnel on Day 1, two cleaning out the rosin tank and two adjusting the batch. Finally, the samples making up group ***c*** mainly from personnel involved in bagging rosin (on both days) and fron static samples taken near the rosin tank. The TRA composition of the samples in groups ***a*** and ***b*** quite closely resemble that obtained from the bulk rosin sample involved in the respective operations. However, in the case of group ***c*** there seems to be some differences between the bulk composition of the rosin being bagged and that obtained from the corresponding air samples.

## 2.4 Factory 13

Worksheets OH389/93, OH390/93, OH391/93 & OH392/93

40 samples:- 13 × LVF-25P
1 × LVF-25S
13 × LVT-P
1 × LVT-S
6 × HVF-60S
6 × Bulk Rosin

Table 6 summarises the terpene concentrations obtained from the charcoal tubes samples at this factory. In general the levels are fairly uniformly low with levels of α-pinene, β-pinene and sesquiterpenes typically in the range of 0 - 25 μg/m³.

**TABLE 6: Summary of Results at Factory 13 (Volatiles)**

| Sample Number | Sample Type | Sample Volume (l) | α-Pinene (μg/m³) | β-Pinene (μg/m³) | Limonene (μg/m³) | Sesquiterpenes (μg/m³) |
|---|---|---|---|---|---|---|
| LN/10599/93 | LVT-P | 275 | 24 | 18 | N/D | 26 |
| LN/10600/93 | LVT-P | 243 | 6 | 17 | N/D | 5 |
| LN/10601/93 | LVT-P | 337 | 12 | 16 | N/D | 7 |
| LN/10602/93 | LVT-P | 285 | 16 | 13 | N/D | 6 |
| LN/10603/93 | LVT-P | 297 | 14 | 12 | N/D | 3 |
| LN/10604/93 | LVT-P | 226 | 28 | 12 | N/D | 7 |
| LN/10605/93 | LVT-P | 280 | 21 | 12 | N/D | 11 |
| LN/10606/93 | LVT-P | 225 | 8 | 11 | N/D | 2 |
| LN/10607/93 | LVT-P | 226 | 197 | 12 | N/D | 132 |
| LN/10608/93 | LVT-P | 270 | 99 | 10 | N/D | 11 |
| LN/10609/93 | LVT-P | 262 | 23 | 9 | N/D | 15 |
| LN/10610/93 | LVT-P | 267 | 13 | 10 | N/D | 453 |
| LN/10612/93 | LVT-P | 103 | N/D | 11 | N/D | 18 |
| LN/10613/93 | LVT-S | 104 | N/D | 12 | N/D | 21 |
| LN/10593/93 | Bulk Rosin | **** | Borneol, α-Terpineol, Sesquiterpenes | | | |
| LN/10594/93 | Bulk Rosin | **** | Limonene, Longifolene | | | |
| LN/10595/93 | Wire/Flux | **** | α-Pinene | | | |
| LN/10596/93 | Wire/Flux | **** | α-Pinene, Limonene, Longifolene | | | |
| LN/10597/93 | Wire/Flux | **** | α-Pinene, α-Terpinene, Limonene, Bornyl Chloride, α-Terpineol, Sesquiterpenes | | | |
| LN/10598/93 | Activator | **** | Amine hydrochloride (by FT-IR) | | | |

Three samples (LN/10607/93, LN/10608/93 and LN/10610/93) showed concentrations of one or more terpene components which were outside this range. LN/10607/93 (obtained from a worker in the reclamation area) had an α-pinene concentration of 197 μg/m³ and a

sesquiterpene concentration of 132 µg/m³, LN/10608/93 (obtained from a worker breaking rosin from a drum in the solid flux department) had an α-pinene concentration of 99 µg/m³ and LN/10610/93 (obtaimed from a worker involved in the preparation of solid flux) had a sesquiterpene concentration of 453 µg/m³. There is no obvious reason for any of these high results, and it is noticeable that a high level of one of the major terpene compcnents does not automatically mean high levels of the others.

The volatile terpene components obtained from ethereal solutions of the six bulk samples are also shown in Table 6. Apart from samples LN/10593/93 (Rosin 132) and LN/10597/93 (flux from mixed scrap solder) the concentrations of these components in the rosin/flux materials supplied was extremely low. The Rosin 132 contained a prominant α-terpineol peak similar to that previously seen in samples of American Rosin WW (see report II in the series of internal reports into the components of solder fume). Sample LN/10597/93 contained a mixture of terpenes, including α-pinene, limonene, α-terpineol and various sesquiterpenes, none of which was particularly dominant. A terpene chloride (possibly bornyl chloride) was also identified in LN/10597/93. The other three rosin/flux samples contained only extremely small amounts of the components listed in Table 6.

The activator sample (LN/10598/93) was tentatively identified by FT-IR as an amine hydrochloride. The sample was analysed as a nujol mull between KBr plates as unlike the rosin/flux samples it had proved to be relatively unsoluble in ether.

Table 7 shows the results of the filter samples for airborne resin acid levels, as well as the resin acid composition of the six bulk samples. Of the 20 air samples, 14 were low volume (13 personal and 1 static) and 6 were high volume. The 14 low volume samples showed 2 giving TRA concentration below the detection limit, 5 giving levels between the detection limit and 50 µg/m³, 2 between 50 and 100 µg/m³, 2 between 100 and 500 µg/m³ and the remaining 2 levels of over 500 µg/m³. The 4 high volume samples all gave concentrations below 4 µg/m³, with 1 below the detection limit of 0.5 µg/m³. The results of these high volume samples suggest typical background TRA concentrations of around 1 - 4 µg/m³ in this factory. The two highest TRA concentrations over 500 µg/m³ (LN/10589/93 and LN/10590/93) both occured in the furnace area of the plant suggesting that this is a potential problem area. Elsewhere in the plant however, the pattern of high and low TRA concentrations does not seem very consistent as shown by the following examples.

a) Samples LN/10618/93 and LN/10619/93 were both taken from employees working on drawing machines, but whereas the former gave a TRA concentration of 6 µg/m³, in the latter it was over 30 times higher at 222 µg/m³. The fact that the composition of the fume collected on the two samples also differed markedly suggests that two different fluxes may have been involved, although the work-sheet suggests that both employees were using 1130 Flux (LN/10595/93).

b) Samples LN/10616/93 and LN/10617/93 were both taken from employees working in the press area, but the TRA concentration of 95 µg/m³ obtained from the former was around 7 times higher than that obtained from the latter. In this case however, the two samples were taken from employees working with different fluxes. Sample LN/10616/93 was from a person working with 366 Flux (LN/10596/93), whilst sample LN/10617/93 was from a person working with 1130 flux (LN/10595/93).

## TABLE 7: Summary of Results at Factory 13 (Resin Acids)

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| LN/10589/93 | LVF-25P | 103 | 651 | 40% Dha, 6% Iso, 4% Pim, 3% Abi, 3% San, 2% Pal, 2% Neo, 40% Other |
| LN/10590/93 | LVF-25S | 104 | 842 | 42% Dha, 5% Iso, 4% Pim, 4% Abi, 4% San, 3% Pal, 2% Neo, 36% Other |
| LN/10616/93 | LVF-25P | 275 | 95 | 58% Abi, 9% Pim, 9% Pal, 9% Dha, 6% Iso, 5% Neo, 1% San, 3% Other |
| LN/10617/93 | LVF-25P | 243 | 13 | 30% Dha, 16% Iso, 16% Abi, 11% Pal, 27% Other |
| LN/10618/93 | LVF-25P | 337 | 6 | 29% Pal, 25% Dha, 18% Abi, 17% Iso, 11% Other |
| LN/10619/93 | LVF-25P | 285 | 222 | 45% Abi, 16% Dha, 12% Pim, 10% Pal, 7% Iso, 3% San, 2% Neo, 5% Other |
| LN/10620/93 | LVF-25P | 297 | N/D | **** |
| LN/10621/93 | LVF-25P | 226 | N/D | **** |
| LN/10622/93 | LVF-25P | 280 | 7 | Too low to accurately assess - appears mainly Dha |
| LN/10623/93 | LVF-25P | 225 | 25 | 22% Dha, 18% Abi, 14% Iso, 6% Pal, 5% Pim, 5% San, 30% Other |
| LN/10624/93 | LVF-25P | 226 | 43 | 27% Dha, 21% Abi, 11% Iso, 10% Pim, 4% Pal, 4% San, 23% Other |
| LN/10625/93 | LVF-25P | 270 | 63 | 31% Abi, 20% Iso, 13% Dha, 9% Pal, 8% Neo, 6% Pim, 1% San, 12% Other |
| LN/10626/93 | LVF-25P | 267 | 422 | 16% Dha, 12% Iso, 8% Abi, 4% Pal, 2% Neo, 1% Pim, 1% San, 56% Other |
| LN/10627/93 | LVF-25P | 262 | 10 | 27% Abi, 26% Dha, 22% Iso, 12% Pal, 13% Other |
| LN/10630/93 | HVF-60S | 2669 | 1.6 | 27% Pal, 21% Dha, 18% Iso, 11% Abi, 23% Other |
| LN/10631/93 | HVF-60S | 2349 | 1.8 | 37% Pal, 21% Iso, 18% Dha, 8% Abi, 16% Other |
| LN/10632/93 | HVF-60S | 3843 | 3.1 | 40% Pal, 19% Iso, 15% Dha, 8% Abi, 18% Other |
| LN/10633/93 | HVF-60S | 4270 | 3.7 | 29% Pal, 22% Abi, 15% Iso, 13% Dha, 6% Pim, 3% San, 12% Other |
| LN/10634/93 | HVF-60S | 4144 | 2.2 | 42% Pal, 20% Iso, 16% Dha, 8% Abi, 14% Other |
| LN/10635/93 | HVF-60S | 3424 | N/D | **** |
| LN/10593/93 | Bulk Rosin | **** | **** | 34% Abi, 20% Iso, 11% Pal, 10% Neo, 9% Dha, 7% San, 5% Pim, 4% Other |
| LN/10594/93 | Bulk Rosin | **** | **** | 18% Dha, 11% Iso, 6% San, 3% Pal, 2% Pim, 60% Other |
| LN/10595/93 | Wire/Flux | **** | **** | 25% Abi, 15% Dha, 14% Iso, 5% San, 3% Pim, 3% Pal, 1% Neo, 34% Other |
| LN/10596/93 | Wire/Flux | **** | **** | 62% Abi, 9% Pim, 9% Pal, 7% Dha, 6% Neo, 5% Iso, 1% San, 1% Other |
| LN/10597/93 | Wire/Flux | **** | **** | 60% Abi, 10% Pim, 9% Pal, 8% Dha, 6% Neo, 5% Iso, 1% San, 1% Other |
| LN/10598/93 | Activator | **** | **** | **** |

The other sample producing a high TRA concentration (422 µg/m³) was LN/10626/93, which was taken from an employee working in the solid flux department preparation area. The fact that samples indicating much lower TRA levels were taken from other personnel working in the same department (LN/10625/93 and LN/10627/93) suggests that areas of high exposure to airborne resin acids are very localised.

The wide range of resin acid compositions in the bulk samples of rosin/flux (LN/10593/93 - LN/10597/93) is relected in the widely differing resin acid compositions present in the air samples. Amongst the 17 air samples taken with TRA levels above the detection limit, there are probably between 8 and 10 groups of differing resin acid compositions. These groups include two, containing a total of 5 samples, in which PAL is the main resin acid

present, and whose resin acid composition bears little resemblance to any of the bulk rosin/flux samples analysed.

Analysis of the bulk sample of activator supplied (LN/10598/93) indicated that it contained little if any resin acid.

## 2.5 Factory 12

Worksheet OH471/93

7 samples:- 2 × LVF-25P
2 × LVT-P
1 × HVF-37S
2 × Bulk Rosin

Table 8 shows the results of the two charcoal tube samples which indicated very low levels of the main terpene species. Other peaks which were present on the chromatograms appeared to be mainly due to the presence of various aliphatic hydrocarbons.

**TABLE 8: Summary of Results at Factory 12 (Volatiles)**

| Sample Number | Sample Type | Sample Volume (l) | α-Pinene (µg/m³) | β-Pinene (µg/m³) | Limonene (µg/m³) | Sesquiterpenes (µg/m³) |
|---|---|---|---|---|---|---|
| NW/60785/93 | LVT-P | 250 | 12 | N/D | N/D | 24 |
| NW/60786/93 | LVT-P | 20 | 4 | N/D | N/D | 19 |

Table 9 shows the results of the 3 filter samples for airborne resin acid levels, as well as the resin acid composition of the 2 bulk rosin samples supplied. TRA concentrations in all 3 air samples were low (< 11 µg/m³), with one being below the detection limit. In fact the static background air sample gave a slightly higher TRA reading than the two personal samples suggesting that background and personal exposures are essentially little different.

The resin acid composition of the air samples was difficult to properly assess due to the relatively low filter loadings, but DHA appeared to be the major component present on both filters on which resin acids levels were above the detection limit. In addition, levels of ABI on both filters appeared to be fairly low. The bulk raw rosin (NW/60783/93) was found to have a resin acid composition in which ABI was the major component. Such a composition is typical of that found in samples of unprocessed rosin analysed previously. The resin acid content of the bulk sample of emulsified rosin (NW/60784/93) showed a proportion of DHA which was significantly increased compared with that in the unprocessed rosin, and a proportion of ABI which was significantly reduced. This suggests that the emulsifying process results in oxidation/degradation of the original rosin.

## TABLE 9: Summary of Results at Factory 12 (Resin Acids)

| Sample Number | Sample Type | Sample Volume (l) | TRA ($\mu g/m^3$) | Sample Composition |
|---|---|---|---|---|
| NW/60779/93 | LVF-25P | 250 | 5 | Too low to accurately assess - appears mainly Dha |
| NW/60780/93 | LVF-25P | 20 | N/D | **** |
| NW/60781/93 | HVF-37S | 12320 | 11 | 36% Dha, 12% Pal/Iso, 8% San, 5% Abi, 3% Pim, 1% Neo, 35% Other |
| NW/60783/93 | Bulk Rosin | **** | **** | 47% Abi, 26% Dha, 9% Pal, 6% Iso, 4% Neo, 2% Pim, 1% San, 5% Other |
| NW/60784/93 | Bulk Rosin | **** | **** | 41% Dha, 28% Abi, 8% Pal, 3% Neo, 2% Iso, 1% San, 1% Pim, 16% Other |

## 3. HOT MELT GLUE USERS

### 3.1 Factory 16

Worksheet OH414/93

19 samples:- 7 × LVF-25P
7 × LVT-P
3 × HVF-60S
2 × Bulk Glue Samples

Table 10 shows the results of the 7 charcoal tube samples which indicated very low levels of the main terpene species present - namely α-pinene, β-pinene and sesquiterpenes. No concentrations higher than 8 µg/m³ were found in any of the samples taken. Some toluene and xylene was also present in the volatile fraction of the samples, but levels were generally less than 30 µg/m³.

Table 11 summarises the results of the filter samples for airborne resin acid levels, as well as the composition of the 2 bulk glue samples supplied. None of the air samples showed TRA concentrations above the detection limit. In the case of the low volume samples this detection limit is typically around 2.5 µg/m³, and for the high volume samples it is around 0.6 µg/m³.

The sample of Fentac hot melt adhesive (LN/10710/93) was found to have a resin acid content comprising around 86% DHA, 8% PAL and 6% ABI. However, it was estimated that the resin acids probably made up only a few percent of the total mass of the glue sample. The sample of water-based Fenflex glue (LN/10711/93) was analysed in the Circle Cell in the FTIR and found to have an infra-red spectrum consistent with that of a starch or dextrin based compound.

**TABLE 10: Summary of Results at Factory 16 (Volatiles)**

| Sample Number | Sample Type | Sample Volume (l) | α-Pinene (µg/m³) | β-Pinene (µg/m³) | Limonene (µg/m³) | Sesquiterpenes (µg/m³) |
|---|---|---|---|---|---|---|
| LN/10712/93 | LVT-P | 285 | < 1 | 3 | N/D | 3 |
| LN/10713/93 | LVT-P | 268 | < 1 | 3 | N/D | 1 |
| LN/10714/93 | LVT-P | 269 | 1 | 4 | N/D | 2 |
| LN/10715/93 | LVT-P | 263 | 1 | 3 | N/D | 1 |
| LN/10716/93 | LVT-P | 260 | 2 | 4 | N/D | 8 |
| LN/10717/93 | LVT-P | 273 | 4 | 5 | N/D | 4 |
| LN/10718/93 | LVT-P | 260 | 1 | 3 | N/D | 1 |

## TABLE 11: Summary of Results at Factory 16 (Resin Acids)

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| LN/10699/93 | LVF-25P | 285 | N/D | **** |
| LN/10700/93 | LVF-25P | 268 | N/D | **** |
| LN/10701/93 | LVF-25P | 269 | N/D | **** |
| LN/10702/93 | LVF-25P | 263 | N/D | **** |
| LN/10703/93 | LVF-25P | 260 | N/D | **** |
| LN/10704/93 | LVF-25P | 273 | N/D | **** |
| LN/10705/93 | LVF-25P | 260 | N/D | **** |
| LN/10707/93 | HVF-60S | 2056 | N/D | **** |
| LN/10708/93 | HVF-60S | 2570 | N/D | **** |
| LN/10709/93 | HVF-60S | 2580 | N/D | **** |
| LN/10710/93 | Bulk Glue | **** | **** | 86% Dha, 8% Pal, 6% Abi |
| LN/10711/93 | Bulk Glue | **** | **** | Infra-red spectrum consistent with starch/dextrin compound |

### 3.2 Factory 17

Worksheet OH415/93

17 samples:- 6 × LVF-25P
6 × LVT-P
4 × HVF-60S
1 × Bulk Glue Samples

Table 12 shows the results of the 6 charcoal tube samples which indicated generally consistent levels of the main terpene species throughout the workplace area. α-Pinene was typically in the range 40 - 50 µg/m³, sesquiterpenes 20 - 50 µg/m³ and β-pinene 5 - 10 µg/m³. Similar concentrations of toluene and xylene were also present in the volatile fraction of most of the samples.

Table 13 summarises the results of the filter samples for airborne resin acid levels, as well as the composition of the sample of hot melt glue supplied. Only one of the air samples gave a TRA concentration above the detection limit (which is around 2.5 µg/m³ for the low volume samples and 0.6 µg/m³ for the high volume samples), and even this was too low to be able to accurately assess the resin acid composition.

The sample of Mydrin WB700 hot melt glue (LN/10733/93) was found to have a resin acid content composed mainly of ABI (37%) with around 20% each of PAL and NEO, 10% of PIM and 7% of DHA. For this particular glue it was estimated that resin acids made up a large proportion of the total mass of the glue.

## TABLE 12: Summary of Results at Factory 17 (Volatiles)

| Sample Number | Sample Type | Sample Volume (l) | α-Pinene (µg/m³) | β-Pinene (µg/m³) | Limonene (µg/m³) | Sesquiterpenes (µg/m³) |
|---|---|---|---|---|---|---|
| LN/10734/93 | LVT-P | 257 | 48 | 9 | N/D | 33 |
| LN/10735/93 | LVT-P | 230 | 38 | 10 | N/D | 24 |
| LN/10736/93 | LVT-P | 251 | 38 | 10 | N/D | 24 |
| LN/10737/93 | LVT-P | 254 | 43 | 8 | N/D | 55 |
| LN/10738/93 | LVT-P | 250 | 50 | 5 | N/D | 22 |
| LN/10739/93 | LVT-P | 236 | 53 | 7 | N/D | 22 |

## TABLE 13: Summary of Results at Factory 17 (Resin Acids)

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| LN/10720/93 | LVF-25P | 257 | N/D | **** |
| LN/10721/93 | LVF-25P | 230 | N/D | **** |
| LN/10722/93 | LVF-25P | 251 | N/D | **** |
| LN/10723/93 | LVF-25P | 254 | N/D | **** |
| LN/10724/93 | LVF-25P | 250 | N/D | **** |
| LN/10725/93 | LVF-25P | 236 | 4.3 | Too low to accurately assess |
| LN/10728/93 | HVF-60S | 2750 | N/D | **** |
| LN/10729/93 | HVF-60S | 2750 | N/D | **** |
| LN/10730/93 | HVF-60S | 2378 | N/D | **** |
| LN/10731/93 | HVF-60S | 2760 | N/D | **** |
| LN/10733/93 | Bulk Glue | **** | **** | 37% Abi, 21% Pal, 18% Neo, 10% Pim, 7% Dha, 5% Iso, 2% San |

### 3.3 Factory 15

Worksheet OH416/93

32 samples:- 12 × LVF-25P
12 × LVT-P
6 × HVF-60S
2 × Bulk Glue Samples

Table 14 shows the results of the 12 charcoal tube samples which indicated somewhat higher levels of the main terpene species than in the other two workplace using hot melt glues. α-Pinene was typically in the range 200 - 800 µg/m³, limonene 170 - 800 µg/m³ and sesquiterpenes 40 - 100 µg/m³. Toluene and xylene were also present in most of the samples in concentrations ranging from around 20 µg/m³ to 870 µg/m³.

## TABLE 14: Summary of Results at Factory 15 (Volatiles)

| Sample Number | Sample Type | Sample Volume (l) | α-Pinene (µg/m³) | β-Pinene (µg/m³) | Limonene (µg/m³) | Sesquiterpenes (µg/m³) |
|---|---|---|---|---|---|---|
| LN/10764/93 | LVT-P | 197 | 279 | N/D | 263 | 39 |
| LN/10765/93 | LVT-P | 193 | 217 | N/D | 169 | 64 |
| LN/10766/93 | LVT-P | 195 | 358 | N/D | 306 | 63 |
| LN/10767/93 | LVT-P | 201 | 809 | N/D | 801 | 100 |
| LN/10768/93 | LVT-P | 198 | 602 | N/D | 666 | 85 |
| LN/10769/93 | LVT-P | 195 | 599 | N/D | 599 | 77 |
| LN/10770/93 | LVT-P | 164 | 225 | N/D | 220 | 46 |
| LN/10771/93 | LVT-P | 174 | 238 | N/D | 276 | 43 |
| LN/10772/93 | LVT-P | 148 | 243 | N/D | 202 | 41 |
| LN/10773/93 | LVT-P | 93 | 252 | N/D | 292 | 49 |
| LN/10774/93 | LVT-P | 166 | 302 | N/D | 307 | 54 |
| LN/10775/93 | LVT-P | 162 | 201 | N/D | 190 | 51 |

## TABLE 15a: Summary of Results at Factory 15 (Resin Acids)

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| LN/10742/93 | LVF-25P | 197 | N/D | **** |
| LN/10743/93 | LVF-25P | 193 | 4 | Too low to accurately assess |
| LN/10744/93 | LVF-25P | 195 | N/D | **** |
| LN/10745/93 | LVF-25P | 201 | 5 | Too low to accurately assess |
| LN/10746/93 | LVF-25P | 198 | N/D | **** |
| LN/10747/93 | LVF-25P | 195 | N/D | **** |
| LN/10748/93 | LVF-25P | 164 | N/D | **** |
| LN/10749/93 | LVF-25P | 174 | N/D | **** |
| LN/10750/93 | LVF-25P | 148 | N/D | **** |
| LN/10751/93 | LVF-25P | 93 | 20 | Too low to accurately assess - appears mainly Iso/Pal/Dha |
| LN/10752/93 | LVF-25P | 166 | 4 | Too low to accurately assess |
| LN/10753/93 | LVF-25P | 162 | N/D | **** |
| LN/10756/93 | HVF-60S | 1850 | 1.7 | Too low to accurately assess - appears mainly Dha |
| LN/10757/93 | HVF-60S | 1850 | 1.2 | Too low to accurately assess - appears mainly Dha |
| LN/10758/93 | HVF-60S | 1850 | 1.2 | Too low to accurately assess - appears mainly Dha |
| LN/10759/93 | HVF-60S | 1830 | N/D | **** |
| LN/10760/93 | HVF-60S | 1830 | 0.9 | Too low to accurately assess - appears mainly Dha |
| LN/10761/93 | HVF-60S | 1830 | N/D | **** |

## TABLE 15b: Summary of Results at Factory 15 (Resin Acids)

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| LN/10762/93 | Bulk Glue | **** | **** | 64% Dha, 21% Abi, 12% Pal, 3% Neo |
| LN/10763/93 | Bulk Glue | **** | **** | 79% Dha, 11% Abi, 10% Pal |

Table 15 summarises the results of the filter samples for airborne resin acid levels, as well as the composition of the 2 bulk hot melt glue samples supplied. 4 of the 12 low volume air samples gave TRA concentrations above the detection limit (typically around 3 µg/m³), but only one (LN/10751/93) was over 5 µg/m³, and even this was insufficiently loaded to be able to accurately assess the resin acid composition. 4 of the 6 high volume samples gave TRA concentrations above the detection limit (typically around 0.8 µg/m³), but none was over 2 µg/m³. Again, such low loadings on the filters prevented any accurate assessment of their resin acid composition other than to say that DHA appeared to be the major component collected.

The sample of Beardow & Adams BAM267 hot melt glue (LN/10762/93) was found to have a resin acid content composed mainly of DHA (64%) with around 20% ABI, 12% PAL and 3% NEO. The resin acid content of the sample of Swiftpack 13 hot melt glue (LN/10763/93) was also found to consist mainly of DHA (79%) together with around 10% each of ABI and PAL. In both glues it was estimated that resin acids made up less than 5% of the total mass of the sample.

## 4. SOLDERERS

### 4.1 Factory 24

Worksheet OH356/93

13 samples:- 9 × LVF-13P
4 × HVF-60S

Table 16 summarises the results of the filter samples for airborne resin acid levels in this factory. Only 2 of the 9 low volume air samples gave TRA concentrations above the detection limit (typically around 4 - 10 µg/m³), with one sample reading 20 µg/m³ and one 101 µg/m³. The resin acid compositions of these two air samples were quite different, with the one at higher concentration containing a much higher proportion of DHA. There is no information available on the specific tasks being carried out by the personnel wearing the 9 samplers, and so it is not possible to see if any relationship exists between exposure to solder fume and different work-tasks. However, the results do suggest that in general exposure to solder fume in this factory is low and that areas of high exposure are fairly localised. All 4 of the high volume samples gave TRA concentrations above the detection limit (typically 0.2 - 0.3 µg/m³), however only one was over 1 µg/m³. These results tend to confirm the observations made from the personal samples above that exposure to solder fume throughout the work-area is generally extremely low (below 1 µg/m³). DHA was the predominant resin acid species present in all four high volume static samples, although the low loading present of all but sample MD/71311/93 means that accurate assessment of their resin acid composition is again difficult.

**TABLE 16: Summary of Results at Factory 24 (Resin Acids)**

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| MD/71298/93 | LVF-13P | 202.5 | N/D | **** |
| MD/71299/93 | LVF-13P | 135.1 | N/D | **** |
| MD/71300/93 | LVF-13P | 137.3 | 101 | 52% Dha, 7% Pim, 6% Abi, 4% Iso, 3% San, 3% Neo, 2% Pal, 23% Other |
| MD/71301/93 | LVF-13P | 146.3 | 20 | 27% Dha, 23% Iso, 15% Abi, 6% Pim, 5% Neo, 3% San, 2% Pal, 19% Other |
| MD/71302/93 | LVF-13P | 176.2 | N/D | **** |
| MD/71303/93 | LVF-13P | 75.0 | N/D | **** |
| MD/71304/93 | LVF-13P | 28.7 | N/D | **** |
| MD/71305/93 | LVF-13P | 20.5 | N/D | **** |
| MD/71308/93 | LVF-13P | 32.5 | N/D | **** |
| MD/71309/93 | HVF-47S | 6719 | 0.38 | 23% Dha, 13% Pal, 9% Iso, 8% San, 7% Abi, 3% Pim, 37% Other |
| MD/71310/93 | HVF-47S | 10656 | 0.33 | 31% Dha, 16% Pal, 13% Abi, 12% Iso, 6% Pim, 22% Other |
| MD/71311/93 | HVF-47S | 7515 | 2.52 | 51% Dha, 18% Abi, 11% Iso, 6% Pal, 4% Pim, 10% Other |
| MD/71312/93 | HVF-47S | 14912 | 0.25 | 34% Dha, 12% Iso, 12% Pal, 9% Abi, 5% Pim, 28% Other |

## 4.2 Factory 18

Worksheet OH357/93

14 samples:- 10 × LVF-13P
4 × HVF-60S

Table 17 summarises the results of the filter samples for airborne resin acid levels in this factory. All 10 of the low volume air samples gave TRA concentrations above the detection limit (typically around 5 µg/m³). Four gave readings of less than 50 µg/m³, 4 were between 50 and 100 µg/m³ and the remaining 2 between 100 and 200 µg/m³. The resin acid compositions for 9 of the 10 low volume air samples were generally fairly similar, the exception being sampie MD/71324/93 which contained a noticably higher proportion of DHA. In the other 9 air samples ABI was the major component with a typical composition being around 30-35% ABI, 15% DHA and ISO, 8% PAL and 5% PIM, NEO and SAN. There is little information available on the specific tasks being carried out by the personnel wearing the 10 personal samplers, and so the possibilities of observing whether any relationships exist between exposure to solder fume and different work-tasks are limited. However, the results do suggest that personal exposure to solder fume in this factory is generally greater than 25 µg/m³, and that personal exposures well in excess of 50 or 100µg/m³ are not uncommon.

**TABLE 17: Summary of Results at Factory 18 (Resin Acids)**

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| MD/71314/93 | LVF-13P | 155 | 152.4 | 34% Abi, 17% Dha, 15% Iso, 10% Pal, 5% Pim, 4% Neo, 4% San, 11% Others |
| MD/71315/93 | LVF-13P | 189 | 91.5 | 37% Abi, 17% Iso, 15% Dha, 8% Pal, 4% Pim, 4% Neo, 4% San, 11% Others |
| MD/71316/93 | LVF-13P | 177 | 25.6 | 30% Abi, 18% Dha, 15% Iso, 7% Pal, 5% Pim, 5% Neo, 4% San, 16% Others |
| MD/71317/93 | LVF-13P | 224.3 | 79.6 | 37% Abi, 16% Iso, 14% Dha, 8% Pal, 5% Neo, 4% Pim, 3% San, 13% Others |
| MD/71318/93 | LVF-13P | 166.6 | 73.5 | 36% Abi, 16% Iso, 13% Dha, 10% Pal, 6% Neo, 4% Pim, 4% San, 11% Others |
| MD/71319/93 | LVF-13P | 171 | 60.0 | 37% Abi, 17% Iso, 13% Dha, 7% Pal, 6% Neo, 4% Pim, 4% San, 12% Others |
| MD/71320/93 | LVF-13P | 124 | 24.5 | 23% Abi, 15% Iso, 14% Dha, 7% Pal, 6% Neo, 5% Pim, 5% San, 25% Others |
| MD/71321/93 | LVF-13P | 126 | 24.1 | 28% Abi, 15% Iso, 15% Dha, 7% Pal, 7% Neo, 4% Pim, 4% San, 20% Others |
| MD/71324/93 | LVF-13P | 39.9 | 33.4 | 28% Dha, 10% Abi, 8% Pal, 8% Neo, 6% Iso, 6% Pim, 6% San, 28% Others |
| MD/71325/93 | LVF-13P | 51.3 | 197.1 | 34% Abi, 22% Dha, 8% Pal, 8% Pim, 7% Iso, 4% San, 4% Neo, 13% Others |
| MD/71326/93 | HVF-47S | 8253 | 26.1 | 36% Abi, 16% Dha, 15% Iso, 9% Pal, 6% Pim, 4% San, 3% Neo, 11% Others |
| MD/71327/93 | HVF-47S | 7370 | 28.6 | 38% Abi, 16% Iso, 14% Dha, 8% Pal, 5% Pim, 4% San, 2% Neo, 13% Others |
| MD/71328/93 | HVF-47S | 6837 | 4.9 | 24% Abi, 21% Dha, 15% Iso, 8% Pal, 6% Pim, 6% San, 3% Neo, 17% Others |
| MD/71329/93 | HVF-47S | 6048 | 0.5 | Too low to accurately assess - appears mainly Dha |

All 4 of the high volume samples gave TRA concentrations above the detection limit (typically 0.2 µg/m³). The control sample taken in an office area (MD/71329/93) gave a low reading of only 0.5 µg/m³. The other 3 samples suggested general background levels of TRA of around 5 µg/m³ in the Transmitter Assembly Area, and of between 25 and 30

µg/m³ in the PCB and RX Assembly Areas (these latter two values seem quite high for background readings). The resin acid compositions of the 3 high volumes samples taken in the work areas was generally similar to those observed above for the personal samples. The filter loading for the control sample taken in the office area was too low for the resin acid composition to be accurately assessed.

### 4.3 Factory 23

Worksheet OH384/93

12 samples:- 8 × LVF-13P
4 × HVF-60S

Table 18 summarises the results of the filter samples for airborne resin acid levels in this factory. All 8 of the low volume air samples gave TRA concentrations above the detection limit (typically around 5 µg/m³). Five gave readings of less than 50 µg/m³, 1 was between 50 and 100 µg/m³ and the remaining 2 between 100 and 200 µg/m³. The resin acid compositions for the 8 low volume air samples seem to fall into one of the following three groups:-

a) Samples in which DHA makes up some 35-40% of the TRA collected, with around 15% PIM, 10% ISO and ABI and 5% each of PAL, NEO and SAN. This group comprises 5 of the 8 samples, all of which were taken on the top floor.

b) Samples in which ABI, DHA and ISO each make up around 25% of the TRA collected, with PIM, PAL, NEO and SAN combined making up most of the remaining 25%. This group contains 2 of the 8 samples, both of which were taken on the ground floor.

c) Samples in which ABI and DHA each make up around 30% of the TRA collected, with the remainder consisting of around 13% PIM, 8% ISO, 6% PAL and SAN and 3% NEO. This group contains only 1 of the 8 samples, and was taken on the ground floor.

There is little information available on the specific tasks being carried out by the personnel wearing the 10 personal samplers, and so the possibilities of observing whether any relationships exist between exposure to solder fume and different work-tasks are limited. However, it is noticable that the first five samples (MD/71376-80/93), which were taken on the top floor of the building, show significantly lower TRA exposures than samples MD/71381-83/93 which were taken on the ground floor. Indeed, whilst all 5 top floor samples indicate personal exposures less than 50 µg/m³, those taken on the ground floor are all greater than 50 µg/m³, and indeed 2 of the 3 samples give results of greater than 100 µg/m³.

All 4 of the high volume samples gave TRA concentrations above the detection limit (typically 0.15 µg/m³). The control sample taken on the middle floor (MD/71389/93) gave the lowest reading of only 2 µg/m³. The 2 samples taken on the top floor gave readings of 55 and 39 µg/m³, both of which seem rather high in comparison with the 17 - 43 µg/m³ range of results obtained from the 5 personal samples taken on this floor. The remaining sample, taken on the ground floor, gave a reading of 52 µg/m³, again a fairly high result, but one which is consistent with the generally high personal sampler results on this floor. The resin acid compositions of the 3 high volumes samples taken on the top and ground floors are fairly similar, but differ from that found in any of the three groups of personal samples (see above), in that they contain ABI as the main resin acid constituent.

Typically, the resin acid content of these samples comprises around 40 - 45% ABI, 15% DHA, 10% PAL, PIM and ISO and 4% NEO and SAN. The resin acid composition of the control sample is different, and fairly closely resembles that found in group ***b*** of the personal samples above.

**TABLE 18: Summary of Results at Factory 23 (Resin Acids)**

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| MD/71376/93 | LVF-13P | 207 | 33 | 36% Dha, 18% Pim, 15% Abi, 11% Iso, 4% San, 3% Pal, 3% Neo, 10% Others |
| MD/71377/93 | LVF-13P | 201.2 | 43 | 40% Dha, 19% Pim, 12% Abi, 9% Iso, 4% San, 3% Pal, 2% Neo, 11% Others |
| MD/71378/93 | LVF-13P | 191.5 | 21 | 39% Dha, 18% Pim, 12% Iso, 7% Abi, 4% San, 3% Pal, 2% Neo, 15% Others |
| MD/71379/93 | LVF-13P | 188.3 | 17 | 40% Dha, 14% Pim, 10% Iso, 6% Abi, 6% Pal, 4% San, 3% Neo, 17% Others |
| MD/71380/93 | LVF-13P | 185.3 | 21 | 41% Dha, 14% Pim, 11% Iso, 8% Abi, 5% San, 3% Pal, 2% Neo, 17% Others |
| MD/71381/93 | LVF-13P | 201 | 132 | 30% Dha, 30% Abi, 13% Pim, 8% Iso, 6% Pal, 3% San, 2% Neo, 8% Others |
| MD/71382/93 | LVF-13P | 189 | 64 | 27% Abi, 23% Iso, 21% Dha, 8% Pim, 6% Pal, 6% San, 3% Neo, 6% Others |
| MD/71383/93 | LVF-13P | 178.5 | 131 | 25% Abi, 24% Iso, 24% Dha, 9% Pim, 7% San, 4% Pal, 2% Neo, 5% Others |
| MD/71386/93 | HVF-47S | 6474 | 55 | 44% Abi, 16% Dha, 11% Pal, 9% Pim, 9% Iso, 4% Neo, 3% San, 4% Others |
| MD/71387/93 | HVF-47S | 8466 | 39 | 45% Abi, 16% Dha, 11% Pal, 9% Pim, 8% Iso, 3% San, 3% Neo, 5% Others |
| MD/71388/93 | HVF-47S | 9619 | 52 | 40% Abi, 15% Iso, 13% Dha, 11% Pal, 7% Pim, 5% San, 4% Neo, 5% Others |
| MD/71389/93 | HVF-47S | 8200 | 2 | 30% Abi, 21% Dha, 15% Iso, 9% Pal, 8% Pim, 7% San, 10% Others |

## 4.4 Factory 25

Worksheet OH434/93

15 samples:- 11 × LVF-13P
4 × HVF-60S

Table 19 summarises the results of the filter samples for airborne resin acid levels in this factory. The results from the low volume air samples were all extremely low, with 10 of the 11 samples taken indicating giving TRA concentrations below the detection limit (typically around 3 - 10 µg/m³). The one remaining sample (MD/71582/93) gave a result of 6.3 µg/m³ which itself was only 20% above the detection limit. Given these low sample loadings no information could be gathered on the resin acid content of the fume collected.

3 of the 4 of the high volume samples also gave TRA concentrations below the detection limit (typically 0.1 - 0.3 µg/m³), with the remaining sample (MD/71593/93) giving a result of 0.18 µg/m³ which was only slightly above its detection limit of 0.13 µg/m³. As with the personal samples, these low filter loadings meant that no information on the resin acid content of the air samples could be obtained.

The only conclusion from this set of samples is that both personal and background levels of TRA are extremely low in this factory - probably due mainly to the relatively small amounts of hand soldering being carried out and to good extraction of the little fume that is produced.

## TABLE 19: Summary of Results at Factory 25 (Resin Acids)

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| MD/71580/93 | LVF-13P | 212.2 | N/D | **** |
| MD/71581/93 | LVF-13P | 193.2 | N/D | **** |
| MD/71582/93 | LVF-13P | 126.4 | 6.3 | Too low to accurately assess |
| MD/71583/93 | LVF-13P | 189 | N/D | **** |
| MD/71584/93 | LVF-13P | 146 | N/D | **** |
| MD/71585/93 | LVF-13P | 72.5 | N/D | **** |
| MD/71586/93 | LVF-13P | 40 | N/D | **** |
| MD/71587/93 | LVF-13P | 163.3 | N/D | **** |
| MD/71590/93 | LVF-13P | 182.5 | N/D | **** |
| MD/71591/93 | LVF-13P | 33.3 | N/D | **** |
| MD/71592/93 | LVF-13P | 130 | N/D | **** |
| MD/71593/93 | HVF-47S | 15191 | 0.2 | Too low to accurately assess |
| MD/71594/93 | HVF-47S | 11869 | N/D | **** |
| MD/71595/93 | HVF-47S | 5927 | N/D | **** |
| MD/71596/93 | HVF-47S | 9024 | N/D | **** |

### 4.5 Factory 22

Worksheet OH542/93

11 samples:- 8 × LVF-13P
3 × HVF-60S

Table 20 summarises the results of the filter samples for airborne resin acid levels in this factory. 6 of the 8 low volume air samples gave TRA concentrations above the detection limit (typically around 3 µg/m³ for samples MD/72009-14/93 and 50 µg/m³ for samples MD/72015-16/93). Of the 6 samples giving readings above the detection limit, 2 indicated personal exposures of less than 50 µg/m³, 3 were between 50 and 100 µg/m³ (one of which was an extremely low volume sample with a corresponding high detection limit of just over 50 µg/m³) and the remaining sample was over 1000 µg/m³. The resin acid compositions for 5 of the 6 samples was fairly similar at around 40 - 45% ABI, 17 - 22% DHA, 10 - 15% PIM and PAL, 5 - 10% ISO, 5% NEO and 2% SAN. The remaining sample (MD/72015/93) had a resin acid composition with somewhat less ABI, however the filter loading was only some 1½ times the detection limit and so accurate assessment of the resin acid ratios present was difficult.

Once again little information was provided on the specific tasks being carried out by the individuals wearing the 8 personal samplers. Whilst this limits the possibilities of observing whether any relationships exist between solder fume exposure and different

work-tasks, it is possible to compare results obtained from personnel who appear from the available information to be carrying out similar jobs. Samples MD/72013/93 and MD/72014/93 show two workers doing the same job in the same area and experiencing similar personal TRA exposures of around 15 µg/m³. However, this is not the case with samples MD/72010/93 and MD/72011/93, which again were taken from two workers doing the same job, but show personal exposures to be 95 µg/m³ in the former but less than the detection limit of around 3 µg/m³ in the latter. The sample which really stands out from the others is MD/72012/93, which at 1001 µg/m³ is over 10 times higher than any of the other 7 samples, although the reasons for this very high result remain unknown.

2 of the 3 high volume samples gave TRA concentrations above the detection limit (typically 0.3 - 0.7 µg/m³). The sample in which the resin acid content was below the detection limit was the control sample taken in the Electronic Production Office. The 2 samples taken in the PCB Area gave readings of 5 and 23 µg/m³, results which are consistent with the personal sampler results taken in this area. The resin acid compositions of these 2 high volumes samples are generally similar to those outlined above for the personal samples, with ABI the predominant species present.

**TABLE 20: Summary of Results at Factory 22 (Resin Acids)**

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| MD/72005/93 | HVF-60S | 2721 | N/D | **** |
| MD/72006/93 | HVF-60S | 7243 | 23 | 50% Abi, 14% Dha, 10% Pal, 9% Pim, 6% Iso, 4% Neo, 1% San, 6% Others |
| MD/72007/93 | HVF-60S | 5939 | 5 | 39% Abi, 16% Dha, 14% Pal, 9% Pim, 7% Iso, 5% Neo, 3% San, 7% Others |
| MD/72009/93 | LVF-13P | 189 | 87 | 39% Abi, 22% Dha, 17% Pim, 10% Iso, 4% Pal, 3% Neo, 2% San, 3% Others |
| MD/72010/93 | LVF-13P | 186 | 95 | 45% Abi, 17% Dha, 11% Pal, 9% Pim, 8% Iso, 3% Neo, 1% San, 6% Others |
| MD/72011/93 | LVF-13P | 185 | N/D | **** |
| MD/72012/93 | LVF-13P | 177 | 1001 | 43% Abi, 16% Dha, 14% Pal, 9% Pim, 6% Iso, 5% Neo, 2% San, 5% Others |
| MD/72013/93 | LVF-13P | 172 | 12 | 46% Abi, 23% Dha, 8% Pim, 8% Pal, 5% Iso, 5% Neo, 2% San, 3% Others |
| MD/72014/93 | LVF-13P | 169 | 16 | 43% Abi, 20% Dha, 10% Pal, 9% Pim, 8% Neo, 7% Iso, 1% San, 2% Others |
| MD/72015/93 | LVF-13P | 12 | 83 | 25% Abi, 18% Dha, 16% Iso, 14% Pal, 13% Neo, 9% Pim, 5% Others |
| MD/72016/93 | LVF-13P | 10 | N/D | **** |

## 4.6 Factory 21

Worksheet OH543/93

15 samples:- 11 × LVF-13P
4 × HVF-60S

Table 21 summarises the results of the filter samples for airborne resin acid levels in this factory. 9 of the 11 low volume air samples gave TRA concentrations above the detection limit (typically 3 - 18 µg/m³). Five gave readings of less than 50 µg/m³, 2 between 50 and 100 µg/m³, 1 between 100 and 200 µg/m³ and the remaining 1 was over 1000 µg/m³. between 100 and 200 µg/m³. The resin acid compositions for the low volume air samples seem to be split into samples with ABI as the predominant resin acid (3 samples), samples with DHA as the predominant acid (4 samples) and samples containing roughly equal proportions of ABI and DHA (2 samples).

**TABLE 21: Summary of Results at Factory 21 (Resin Acids)**

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| MD/72019/93 | LVF-13P | 205 | 65 | 46% Abi, 21% Dha, 11% Pim, 7% Iso, 7% Pal, 2% Neo, 1% San, 5% Others |
| MD/72020/93 | LVF-13P | 202 | 1048 | 47% Dha, 9% Abi, 8% Iso, 8% Neo, 5% Pim, 2% Pal, 2% San, 19% Others |
| MD/72021/93 | LVF-13P | 201 | 11 | 31% Abi, 26% Dha, 11% Pim, 8% Iso, 6% Pal, 1% San, 17% Others |
| MD/72022/93 | LVF-13P | 120 | 16 | 32% Abi, 22% Dha, 14% Iso, 10% Pim, 8% Pal, 6% Neo, 3% San, 5% Others |
| MD/72023/93 | LVF-13P | 45 | 51 | 40% Dha, 19% Abi, 19% Iso, 5% Pal, 4% Neo, 2% San, 1% Pim, 10% Others |
| MD/72024/93 | LVF-13P | 183 | 31 | 42% Abi, 19% Dha, 12% Pim, 9% Pal, 7% Iso, 3% Neo, 1% San, 7% Others |
| MD/72025/93 | LVF-13P | 164 | 106 | 28% Dha, 21% Abi, 19% Pim, 10% Iso, 7% Neo, 4% Pal, 2% San, 9% Others |
| MD/72026/93 | LVF-13P | 187 | 8 | 33% Dha, 21% Abi, 11% Pim, 8% Neo, 7% Iso, 6% Pal, 4% San, 10% Others |
| MD/72029/93 | LVF-13P | 34 | N/D | **** |
| MD/72030/93 | LVF-13P | 128 | N/D | **** |
| MD/72031/93 | LVF-13P | 119 | 10 | 39% Dha, 23% Abi, 11% Neo, 10% Pal, 5% Pim, 4% Iso, 4% San, 4% Others |
| MD/72032/93 | HVF-60S | 2171 | N/D | **** |
| MD/72033/93 | HVF-60S | 9095 | 3 | 34% Abi, 29% Dha, 11% Pim, 9% Iso, 7% Pal, 1% San, 1% Neo, 8% Others |
| MD/72034/93 | HVF-60S | 7658 | 4 | 37% Abi, 25% Dha, 12% Pim, 8% Iso, 8% Pal, 4% San, 1% Neo, 5% Others |
| MD/72035/93 | HVF-60S | 8025 | 1 | 32% Dha, 31% Abi, 13% Iso, 8% Pim, 8% Pal, 8% Others |

The personal samples indicate a wide variation in personal exposures in the individuals tested, even though according to the request sheet supplied with the samples all but one of the personnel concerned appear to be engaged in soldering. There is however little other information on the precise tasks being performed, and so the possibility of observing whether any relationships exist between solder fume exposure and different work-tasks are limited. In particular, there is no apparent reason for the extremely high reading of 1048 µg/m³ obtained from sample MD/72020/93. It was noted however that the three

samples taken in the Lead and Winding Sections (MD/72029-31/93 appeared to be fairly low compared with those taken in the Assembly and PCB Sections (MD/72019-26/93).

3 of the 4 high volume samples gave TRA concentrations above the detection limit (typically 0.2 - 0.8 µg/m³), with the one sample which did not being the control sample (MD/72032/93) taken in an office. The 3 samples taken in the work areas gave readings of 3.3 and 4.2 µg/m³ for the two samples taken in the Assembly Section and 0.5 µg/m³ for the sample taken in Winding Section. These higher values in the Assembly Section is in general agreement with the observations made from the personal samples. Resin acid compositions indicate ABI being the commonest resin acid present in the two samples taken in the Assembly Section, whilst ABI and DHA are present in roughly equal amounts in the sample taken from the Winding Section.

## 4.7 Factory 19

Worksheet OH558/93

16 samples:- 12 × LVF-13P
4 × HVF-60S

Table 22 summarises the results of the filter samples for airborne resin acid levels in this factory. All 12 of the low volume air samples gave TRA concentrations above the detection limit (typically 2 - 10 µg/m³). 3 indicated personal exposures of between 50 and 100 µg/m³, 3 between 100 and 250 µg/m³, 4 between 250 and 500 µg/m³ and the remaining 2 between 500 and 1000 µg/m³. The resin acid compositions for samples MD/72126-35/93 are all fairly similar with ABI as the main component and a typical composition of around 30% ABI, 20% DHA, 15% ISO, 10% PAL and 2 - 5% of the other resin acids. The 2 samples adjacent to the flow solder machines show a different resin acid composition with DHA the main component.

The personal samples indicate fairly high personal exposures in the individuals tested, whilst at the same time showing a wide variation in the levels obtained (the lowest reading from any of the 12 samples being 58 µg/m³ and the highest being 781 µg/m³). However, since there is no information on the tasks being performed by the individuals wearing the samplers, it is impossible to determine whether any relationships exist between solder fume exposure and different working situations.

All 4 of the high volume samples, including the control sample taken in an office environment (MD/72136/93), gave TRA concentrations above the detection limit (typically 0.2 - 2 µg/m³). The control sample in the office adjacent to the loading bay gave a reading of 61 µg/m³, which is in fact higher than any of the other 3 samples taken in the work areas. In the PCB assembly area the reading was 39 µg/m³ (MD/72137/93), in the upstairs assembly area it was 60 µg/m³ (MD/72138/93) and in the downstairs assembly area it was 22 µg/m³. The reason for this is unknown, but what is clear is that the general background levels of TRA in this factory appear to be fairly high (> 20 µg/m³), a fact which probably helps to account for the generally high levels of personal exposure described above.

## TABLE 22: Summary of Results at Factory 19 (Resin Acids)

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| MD/72126/93 | LVF-13P | 150 | 58 | 37% Abi, 24% Dha, 19% Iso, 8% Pal, 3% San, 2% Pim, 7% Others |
| MD/72127/93 | LVF-13P | 167 | 97 | 31% Abi, 19% Dha, 13% Iso, 8% Pal, 4% Pim, 2% Neo, 1% San, 15% Others |
| MD/72128/93 | LVF-13P | 167 | 278 | 29% Abi, 18% Dha, 14% Iso, 9% Pal, 5% Neo, 4% San, 3% Pim, 18% Others |
| MD/72129/93 | LVF-13P | 156 | 100 | 27% Abi, 22% Dha, 15% Iso, 7% Pal, 5% Neo, 4% San, 3% Pim, 17% Others |
| MD/72130/93 | LVF-13P | 153 | 254 | 32% Abi, 19% Dha, 14% Iso, 9% Pal, 4% Neo, 4% San, 2% Pim, 16% Others |
| MD/72131/93 | LVF-13P | 160 | 317 | 31% Abi, 19% Dha, 14% Iso, 9% Pal, 4% Neo, 4% San, 2% Pim, 17% Others |
| MD/72132/93 | LVF-13P | 159 | 381 | 31% Abi, 18% Dha, 14% Iso, 10% Pal, 4% Neo, 4% San, 3% Pim, 16% Others |
| MD/72133/93 | LVF-13P | 55 | 177 | 30% Abi, 25% Dha, 14% Iso, 8% Pal, 4% San, 3% Pim, 2% Neo, 14% Others |
| MD/72134/93 | LVF-13P | 163 | 131 | 29% Abi, 23% Dha, 15% Iso, 7% Pal, 4% San, 3% Pim, 3% Neo, 16% Others |
| MD/72135/93 | LVF-13P | 169 | 781 | 31% Abi, 18% Dha, 14% Iso, 10% Pal, 4% San, 3% Pim, 2% Neo, 18% Others |
| MD/72136/93 | HVF-60S | 1080 | 61 | 28% Abi, 23% Dha, 15% Iso, 8% Pal, 4% San, 3% Pim, 1% Neo, 18% Others |
| MD/72137/93 | HVF-60S | 13050 | 39 | 34% Dha, 25% Abi, 12% Iso, 5% Pal, 3% San, 2% Pim, 2% Neo, 17% Others |
| MD/72138/93 | HVF-60S | 10620 | 60 | 31% Abi, 20% Dha, 14% Iso, 9% Pal, 4% San, 3% Pim, 1% Neo, 18% Others |
| MD/72139/93 | HVF-60S | 12925 | 22 | 30% Abi, 18% Dha, 14% Iso, 10% Pal, 4% San, 3% Pim, 2% Neo, 19% Others |
| MD/72140/93 | LVF-13P | 90 | 530 | 52% Dha, 14% Abi, 5% Pal, 3% Iso, 1% Pim, 25% Others |
| MD/72141/93 | LVF-13P | 44 | 70 | 39% Dha, 25% Abi, 11% Pal, 9% Iso, 4% San, 3% Pim, 9% Others |

### 4.8 Factory 27

Worksheet OH433/93

29 samples:- 11 × LVF-25P
4 × LVF-25S
10 × LVT-P
4 × LVT-S

Table 23 summarises the terpene concentrations obtained from the charcoal tubes samples at this factory. The levels are found are generally fairly low with levels of α-pinene and sesquiterpenes typically in the range of 5 - 50 µg/m³. All the samples appeared to contain significant levels of various aromatic hydrocarbons including toluene, xylene and trimethylbenzene, indeed the α-pinene content of 2 samples (NE/31342/93 and NE/31343/93) could not be determined because of a large adjacent aromatic peak.

## TABLE 23: Summary of Results at Factory 27 (Volatiles)

| Sample Number | Sample Type | Sample Volume (l) | α-Pinene (µg/m³) | β-Pinene (µg/m³) | Limonene (µg/m³) | Sesquiterpenes (µg/m³) |
|---|---|---|---|---|---|---|
| NE/31342/93 | LVT-P | 211 | See notes | N/D | N/D | 15 |
| NE/31343/93 | LVT-P | 219 | See notes | N/D | N/D | 10 |
| NE/31344/93 | LVT-P | 198 | 50 | N/D | N/D | 11 |
| NE/31345/93 | LVT-P | 194 | 26 | N/D | N/D | 10 |
| NE/31346/93 | LVT-P | 179 | 14 | N/D | N/D | 14 |
| NE/31347/93 | LVT-P | 190 | 39 | N/D | N/D | 11 |
| NE/31348/93 | LVT-P | 187 | 19 | N/D | N/D | 12 |
| NE/31349/93 | LVT-P | 209 | 21 | N/D | N/D | 53 |
| NE/31350/93 | LVT-P | 189 | 8 | N/D | N/D | 7 |
| NE/31351/93 | LVT-P | < 150 | 10 | N/D | N/D | 7 |
| NE/31352/93 | LVT-S | 204 | 34 | N/D | N/D | 52 |
| NE/31353/93 | LVT-S | 82 - 204 | 21 | N/D | N/D | 26 |
| NE/31354/93 | LVT-S | 197 | 35 | N/D | N/D | 31 |
| NE/31355/93 | LVT-S | 197 | 37 | N/D | N/D | 18 |

Because no information was given on the types of jobs being carried out by the employees wearing the personal samplers it is not possible to determine whether certain jobs gave rise to higher exposure to volatile terpenes than others. However, the results for this factory do appear to show some correlation between samples showing higher α-pinene and sesquiterpene levels and those indicating higher TRA concentrations (see Table 24).

Table 24 shows the results of the filter samples for airborne resin acid levels. All of the 15 low volume air samples taken (13 personal and 1 static) showed TRA concentrations above the detection limit. The range of TRA concentrations indicated by the samples was as follows - 2 between the detection limit and 50 µg/m³, 4 between 50 and 100 µg/m³, 5 between 100 and 500 µg/m³, 1 between 500 and 1000 µg/m³ and the remaining 3 over 1000 µg/m³.

## TABLE 24: Summary of Results at Factory 27 (Resin Acids)

| Sample Number | Sample Type | Sample Volume (l) | TRA (µg/m³) | Sample Composition |
|---|---|---|---|---|
| NE/31357/93 | LVF-25P | 211 | 74 | 33% Dha, 26% Abi, 13% Pim, 9% Iso, 9% Pal, 3% Neo, 1% San, 6% Other |
| NE/31358/93 | LVF-25P | 219 | 66 | 37% Dha, 23% Abi, 13% Pim, 9% Iso, 7% Pal, 2% Neo, 1% San, 8% Other |
| NE/31359/93 | LVF-25P | 198 | 73 | 37% Dha, 24% Abi, 13% Pim, 8% Iso, 7% Pal, 2% Neo, 1% San, 8% Other |
| NE/31360/93 | LVF-25P | 211 | 155 | 33% Abi, 30% Dha, 12% Pim, 9% Pal, 7% Iso, 2% Neo, 1% San, 6% Other |
| NE/31361/93 | LVF-25P | 194 | 153 | 32% Dha, 26% Abi, 11% Pim, 8% Iso, 8% Pal, 3% Neo, 1% San, 11% Other |
| NE/31362/93 | LVF-25P | 179 | 128 | 33% Dha, 27% Abi, 12% Pim, 8% Pal, 8% Iso, 3% Neo, 1% San, 8% Other |

| | | | | |
|---|---|---|---|---|
| NE/31363/93 | LVF-25P | 190 | 164 | 32% Abi, 29% Dha, 12% Pim, 9% Pal, 7% Iso, 3% Neo, 1% San, 7% Other |
| NE/31364/93 | LVF-25P | 187 | 94 | 32% Dha, 27% Abi, 11% Pim, 8% Pal, 7% Iso, 3% Neo, 1% San, 11% Other |
| NE/31365/93 | LVF-25P | 209 | 637 | 37% Abi, 23% Dha, 13% Pim, 7% Pal, 7% Iso, 3% Neo, 2% San, 8% Other |
| NE/31366/93 | LVF-25P | 189 | 40 | 33% Dha, 18% Iso, 13% Abi, 11% Pim, 4% Pal, 3% Neo, 3% San, 15% Other |
| NE/31367/93 | LVF-25P | < 150 | > 15 | 36% Dha, 14% Abi, 13% Pim, 11% Iso, 6% Pal, 6% San, 4% Neo, 10% Other |
| NE/31368/93 | LVF-25S | 204 | 2441 | 33% Abi, 26% Dha, 10% Pim, 10% Pal, 6% Iso, 5% Neo, 2% San, 8% Other |
| NE/31369/93 | LVF-25S | 82 - 204 | 959 - 2385 | 33% Abi, 24% Dha, 10% Pim, 10% Pal, 6% Iso, 6% Neo, 2% San, 9% Other |
| NE/31370/93 | LVF-25S | 197 | 1234 | 37% Abi, 22% Dha, 11% Pal, 10% Pim, 6% Iso, 3% Neo, 2% San, 9% Other |
| NE/31371/93 | LVF-25S | 197 | 291 | 33% Abi, 24% Dha, 10% Pim, 10% Pal, 6% Iso, 3% Neo, 1% San, 13% Other |

No information was provided on the jobs being carried out by the employees wearing the personal samplers, and it is therefore not possible to see whether certain jobs gave rise to higher airborne TRA concentrations than others. Four of the 5 highest readings however, including the 3 over 1000 µg/m³, were static samples taken from around extraction fans used by the two workers wearing personal samples NE/31363/93 and NE/31364/93. It can be seen from the following two sets of results that the TRA levels around the extraction fan were much higher than for the corresponding personal samples.

a) Personal sample NE/31363/93 gave a TRA concentration of 94 µg/m³, whereas the two static samples by the adjacent extraction unit gave readings of between 959 and 2441 µg/m³.

b) Personal sample NE/31364/93 gave a TRA concentration of 164 µg/m³, whereas the two static samples by the adjacent extraction unit gave readings of between 291 and 1234 µg/m³.

Resin acid compositions in the 15 air samples seems to fall into one of the following three groups. The first group, containing 6 samples, has a typical resin acid composition of around 35% DHA, 25% ABI, 12% PIM and 8% each of ISO and PAL. The second group, containing 7 samples, has a typical resin acid compostion of around 35% ABI, 25% DHA, 10% PIM, 10% PAL and 6% ISO. Finally, the third group, containing 2 samples, has a typical resin acid composition of around 35% DHA, 15% ABI, 15% ISO, 10% PIM and 5% PAL.

## 5. SUMMARY OF RESULTS

### 5.1 Resin Acids

The TRA concentrations obtained from the particulate samples taken during the TDS are summarised in Tables 25 tc 28 and Figures 1 to 8. Frcm these tables/figures the following observations were made:-

- The mean TRA concentration of 381.4 µg/m³ obtained from the six rosin manufacturers is around 4 times that from the seven locations carrying out soldering operations and 350 times that from the three premises using hot melt glue.
- For the rosin manufacturers, the mean TRA exposure obtained from the 63 personal samples was 372.6 µg/m³, compared with 406.6 µg/m³ for 22 static samples.
- For the hot melt glue users, the mean TRA exposure obtained from the 25 personal samples was 1.5 µg/m³, compared with 0.4 µg/m³ for the 13 static samples.
- For the solderers, the mean TRA exposure obtained from the 69 personal samples was 103.9 µg/m³, compared with 15.9 µg/m³ for the 27 static samples.
- The biggest difference in TRA concentration between personal and static samples is observed in the soldering group - this may be a consequence of the directional nature of solder fume and the fact that breathing-zone rather than lapel sampling was used for this group of employees.
- Table 28 indicates that out of a total of 219 samples taken, 24% showed TRA levels in excess of 100 µg/m³, with 16% exceeding 200 µg/m³ and 4.5% 1000 µg/m³. In the case of the 157 personal samples, 27% showed TRA exposures in excess of 100 µg/m³, with 23% exceeding 200 µg/m³ and 4.5% 1000 µg/m³.
- The 85 samples taken at rosin manufacturing plants showed 42% with TRA levels in excess of 100 µg/m³, with 32% exceeding 200 µg/m³ and 12% 1000 µg/m³. For the 63 personal samples the porcentages exceeding these three limits were 40%, 27% and 11%.
- Of the 38 samples taken at premises using hot melt glue none exceeded 100 µg/m³ (the highest being 20 µg/m³).
- The 69 personal samples taken at the soldering factories showed 25% with TRA levels in excess of 100 µg/m³, with 12% also exceeding 200 µg/m³, although none exceeded 1000 µg/m³. None of the 27 static samples taken at these factories showed TRA concentrations in excess of 100 µg/m³.
- All three of the factories using hot melt glue and twc of those using solder had mean TRA concentrations of less than 1 µg/m³.
- Four of the rosin manufacturing plants had mean TRA concentrations greater than 100 µg/m³. Of these, two were in excess of 200 µg/m³ with one of these also exceeding 1000 µg/m³.

## TABLE 25: TRA Samples - Summary of Results

| Sample Group | Number of Samples | TRA Concentrations (µg/m³) | | | | |
|---|---|---|---|---|---|---|
| | | Mean | Median | Minimum | Maximum | Range |
| **All Samples** | 219 | 182.9 | 12 | 0 | 3754 | 3754 |
| **Rosin Manufacturers** | 85 | 381.4 | 66 | 0 | 3754 | 3754 |
| Factory 14 | 5 | 99.0 | 8 | 1 | 423 | 422 |
| Factory 11 | 27 | 99.4 | 20 | 0 | 849 | 849 |
| Factory 10 | 15 | 1304.9 | 835 | 201 | 3754 | 3553 |
| Factory 13 | 20 | 120.6 | 8.5 | 0 | 842 | 842 |
| Factory 12 | 3 | 5.3 | 5 | 0 | 11 | 11 |
| **Hot Melt Glue Users** | 38 | 1.1 | 0 | 0 | 20 | 20 |
| Factory 16 | 10 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 17 | 10 | 0.4 | 0 | 0 | 4 | 4 |
| Factory 15 | 18 | 2.1 | 0 | 0 | 20 | 20 |
| **Solderers** | 96 | 79.1 | 21 | 0 | 1048 | 1048 |
| Factory 24 | 13 | 9.6 | 0 | 0 | 101 | 101 |
| Factory 18 | 14 | 58.8 | 31 | 1 | 197 | 196 |
| Factory 23 | 12 | 50.8 | 41 | 2 | 132 | 130 |
| Factory 25 | 15 | 0.4 | 0 | 0 | 6 | 6 |
| Factory 22 | 11 | 120.2 | 16 | 0 | 1001 | 1001 |
| Factory 21 | 15 | 90.3 | 10 | 0 | 1048 | 1048 |
| Factory 19 | 16 | 209.8 | 115.5 | 22 | 781 | 759 |
| Factory 27 | 15 | 482.5 | 153 | 15 | 2441 | 2426 |

## TABLE 26: TRA Personal Samples - Summary of Results

| Sample Group | Number of Samples | TRA Concentrations (µg/m³) | | | | |
|---|---|---|---|---|---|---|
| | | Mean | Median | Minimum | Maximum | Range |
| **All Personal Samples** | 157 | 195.4 | 21 | 0 | 3754 | 3754 |
| **Rosin Manufacturers** | 63 | 372.6 | 63 | 0 | 3754 | 3754 |
| Factory 14 | 2 | 242.5 | 242.5 | 62 | 423 | 361 |
| Factory 11 | 25 | 99.2 | 12 | 0 | 849 | 849 |
| Factory10 | 10 | 1734.7 | 1364.5 | 201 | 3754 | 3553 |
| Factory 13 | 13 | 119.8 | 25 | 0 | 651 | 651 |
| Factory12 | 2 | 2.5 | 2.5 | 0 | 5 | 5 |
| **Hot Melt Glue Users** | 25 | 1.5 | 0 | 0 | 20 | 20 |
| Factory 16 | 7 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 17 | 6 | 0.7 | 0 | 0 | 4 | 4 |
| Factory 15 | 12 | 2.8 | 0 | 0 | 20 | 20 |
| **Solderers** | 69 | 103.9 | 26 | 0 | 1048 | 1048 |
| Factory 24 | 9 | 13.4 | 0 | 0 | 101 | 101 |
| Factory 18 | 10 | 76.3 | 67 | 24 | 197 | 173 |
| Factory 23 | 8 | 57.8 | 38 | 17 | 132 | 115 |
| Factory 25 | 11 | 0.6 | 0 | 0 | 6 | 6 |
| Factory 22 | 8 | 161.8 | 49.5 | 0 | 1001 | 1001 |
| Factory 21 | 11 | 122.4 | 16 | 0 | 1048 | 1048 |
| Factory 19 | 12 | 264.5 | 215.5 | 58 | 781 | 723 |
| Factory 27 | 11 | 145.4 | 94 | 15 | 637 | 622 |

## TABLE 27: TRA Static Samples - Summary of Results

| Sample Group | Number of Samples | TRA Concentrations (µg/m³) | | | | |
|---|---|---|---|---|---|---|
| | | Mean | Median | Minimum | Maximum | Range |
| **All Static Samples** | 62 | 151.3 | 2 | 0 | 2441 | 2441 |
| **Rosin Manufacturers** | 22 | 406.6 | 103 | 0 | 2441 | 2441 |
| Factory 14 | 3 | 3.4 | 1 | 1 | 8 | 7 |
| Factory 11 | 2 | 103.0 | 103 | 71 | 135 | 64 |
| Factory 10 | 5 | 445.2 | 335 | 201 | 835 | 634 |
| Factory 13 | 7 | 122.1 | 2 | 0 | 842 | 842 |
| Factory 12 | 1 | 11.0 | 11 | 11 | 11 | 0 |
| **Hot Melt Glue Users** | 13 | 0.4 | 0 | 0 | 2 | 2 |
| Factory 16 | 3 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 17 | 4 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 15 | 6 | 0.9 | 1 | 0 | 2 | 2 |
| **Solderers** | 27 | 15.9 | 3 | 0 | 61 | 61 |
| Factory 24 | 4 | 0.9 | 0 | 0 | 3 | 3 |
| Factory 18 | 4 | 15.1 | 15 | 1 | 29 | 28 |
| Factory 23 | 4 | 37.0 | 46 | 2 | 55 | 53 |
| Factory 25 | 4 | 0.1 | 0 | 0 | 0 | 0 |
| Factory 22 | 3 | 9.3 | 5 | 0 | 23 | 23 |
| Factory 21 | 4 | 2.0 | 2 | 0 | 4 | 4 |
| Factory 27 | 4 | 45.5 | 50 | 22 | 61 | 39 |
| Factory 27 | 4 | 1409.5 | 1453 | 291 | 2441 | 2150 |

## TABLE 28: TRA Samples - Distribution of Results

| Sample Group | Number of Samples at TRA Concentration | | | | | |
|---|---|---|---|---|---|---|
| | Total | < 10 µg/m³ | 10 - 100 µg/m³ | 100 - 200 µg/m³ | 200 - 1000 µg/m³ | > 1000 µg/m³ |
| **All Samples** | 219 | 104 | 62 | 18 | 25 | 10 |
| Rosin Manufacturers | 85 | 26 | 23 | 9 | 17 | 10 |
| Hot Melt Glue Users | 38 | 37 | 1 | - | - | - |
| Solderers | 96 | 41 | 38 | 9 | 8 | - |
| **Personal Samples** | 157 | 65 | 50 | 17 | 18 | 7 |
| Rosin Manufacturers | 63 | 17 | 21 | 8 | 10 | 7 |
| Hot Melt Glue Users | 25 | 24 | 1 | - | - | - |
| Solderers | 69 | 24 | 28 | 9 | 8 | - |
| **Static Samples** | 62 | 39 | 12 | 1 | 7 | 3 |
| Rosin Manufacturers | 22 | 9 | 2 | 1 | 7 | 3 |
| Hot Melt Glue Users | 13 | 13 | - | - | - | - |
| Solderers | 27 | 17 | 10 | - | - | - |

## 5.2 Volatiles

Volatile samples were taken only at the factories involved in rosin manufacture and using hot melt glues. This was because previous sampling visits to soldering factories had shown airborne concentrations of volatile terpenes to be negligible in comparison with TRA. The concentrations of α-pinene, β-pinene, limonene and sesquiterpenes obtained from the charcoal tube samples are summarised in Tables 29 and 32 and Figures 9 to 16. From these tables/figures the following observations were made:-

- The mean concentration of α-pinene in the 90 charcoal tube samples was 80 µg/m³, with rosin manufacturers averaging 40 µg/m³ and hot melt glue users 184 µg/m³. There was little difference in mean α-pinene concentrations between personal and static samples (with figures of 80 and 84 µg/m³ respectively).
- Wide variations were noted between the mean concentrations of α-pinene in the eight premises at which samples were collected. Three factories, 2 rosin manufacturers and 1 hot melt glue user, produced mean results of less than 10 µg/m³. Three more, 2 rosin manufacturers and 1 hot melt glue user, averaged between 10 and 50 µg/m³. The mean concentration for the remaining rosin manufacturer was around 135 µg/m³, whilst that for the remaining hot melt glue user was over 350 µg/m³.
- 50% of samples showed α-pinene concentrations of less than 10 µg/m³, with 23% below the detection limit. Conversely, 19% of samples gave results in excess of 100 µg/m³, although none exceeded 1000 µg/m³. Samples from rosin manufacturers produced fewer high concentration samples (8% over 100 µg/m³) than those from hot melt glue users (48% over 100 µg/m³).
- The mean concentration of β-pinene in the 92 charcoal tube samples was 5.7 µg/m³, with rosin manufacturers averaging 6.7 µg/m³ and hot melt glue users 3 µg/m³. The average concentration in the 10 static samples was around 17 µg/m³ compared with around 4 µg/m³ in the 82 personal samples.
- Six of the 8 factories visited, 3 rosin manufacturers and 3 hot melt glue users, had average concentrations of β-pinene below 10 µg/m³, with mean values at the other 2 rosin manufacturers both being less than 25 µg/m³. 78% of samples produced results of less than 10 µg/m³, with 47% below the detection limit. None of the 92 samples analysed gave a concentration in excess of 100 µg/m³.
- Limonene was detected in only 17 of the 92 samples taken, and at only two of the eight sites (Resinous Chemicals and Jeyes Group). Whilst all 12 of the samples taken at Jeyes Group produced results in excess of 100 µg/m³, 8 of the 11 samples from Resinous chemicals were below 10 µg/m³, with 6 being below the detection limit.
- The mean concentration of sesquiterpenes in the 92 samples was 214 µg/m³. Rosin manufacturers averaged 281 µg/m³ and hot melt glue users 37 µg/m³. The 10 static samples gave a mean result of 807 µg/m³ compared with 142 µg/m³ in the 82 personal samples. 50% of the samples gave results of less than 10 µg/m³, with 13% below the detection limit. At the other extreme, 9% of results were in excess of 100 µg/m³, with 4% over 2500 µg/m³. Seven of the 8 results above 100 µg/m³ and all 4 of those in excess of 2500 µg/m³ came from rosin manufacturers.
- Two factories, 1 rosin manufacturer and 1 hot melt glue user, produced mean sesquiterpene concentrations below 10 µg/m³, with five more, 3 rosin manufacturers and the remaining 2 hot melt glue users, averaging between 20 and 60 µg/m³. The mean concentration from the remaining rosin manufacturer was up at around 1600 µg/m³, although this particular group of samples did produce a rather extreme range of results (from "not detected" to almost 5000 µg/m³).
- Figures 13 to 16 show little correlation between concentrations of the four volatile terpenes and TRA levels in the TDS samples. In particular, whilst samples taken from users of hot melt glue showed generally high levels of volatile terpenes (particularly α-pinene and limonene), their TRA content was extremely low (on average less than 1 µg/m³). This is probably due to the fact that most hot melt glues are typically used at

between 120 and 180°C - temperatures which are too low to generate significant levels of resin acids.

## TABLE 29: Volatile Samples - Summary of Results

| Sample Group | Number of Samples | Volatile Concentrations (µg/m³) | | | | |
|---|---|---|---|---|---|---|
| | | Mean | Median | Minimum | Maximum | Range |
| **α-Pinene** | 90 | 80.0 | 9 | 0 | 809 | 809 |
| **Rosin Manufacturers** | 65 | 39.9 | 4 | 0 | 610 | 610 |
| Factory 14 | 0 | - | - | - | - | - |
| Factory 11 | 26 | 0.3 | 0 | 0 | 5 | 5 |
| Factory 10 | 11 | 163.3 | 5 | 0 | 610 | 610 |
| Factory 13 | 14 | 32.9 | 15 | 0 | 197 | 197 |
| Factory 27 | 12 | 26.2 | 24 | 8 | 50 | 42 |
| Factory 12 | 2 | 8.0 | 8 | 4 | 12 | 8 |
| **Hot Melt Glue Users** | 25 | 184.2 | 53 | 0 | 809 | 809 |
| Factory 16 | 7 | 1.7 | 1 | 0 | 4 | 4 |
| Factory 17 | 6 | 45.0 | 46 | 38 | 53 | 15 |
| Factory 15 | 12 | 360.4 | 266 | 201 | 809 | 608 |
| **β-Pinene** | 92 | 5.7 | 0.4 | 0 | 80 | 80 |
| **Rosin Manufacturers** | 67 | 6.7 | 0.4 | 0 | 80 | 80 |
| Factory 14 | 0 | - | - | - | - | - |
| Factory 11 | 26 | 0.3 | 0 | 0 | 1 | 1 |
| Factory 10 | 11 | 24.4 | 4 | 0 | 80 | 80 |
| Factory 13 | 14 | 12.5 | 12 | 9 | 18 | 9 |
| Factory 27 | 14 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 12 | 2 | 0.0 | 0 | 0 | 0 | 0 |
| **Hot Melt Glue Users** | 25 | 3.0 | 3 | 0 | 10 | 10 |
| Factory 16 | 7 | 3.6 | 3 | 3 | 5 | 2 |
| Factory 17 | 6 | 8.2 | 9 | 5 | 10 | 5 |
| Factory 15 | 12 | 0.0 | 0 | 0 | 0 | 0 |
| **Limonene** | 92 | 47.7 | 0 | 0 | 801 | 801 |
| **Rosin Manufacturers** | 67 | 1.4 | 0 | 0 | 32 | 32 |
| Factory 14s | 0 | - | - | - | - | - |
| Factory 11 | 26 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 10s | 11 | 8.7 | 0 | 0 | 32 | 32 |
| Factory 13r | 14 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 27 | 14 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 12 | 2 | 0.0 | 0 | 0 | 0 | 0 |
| **Hot Melt Glue Users** | 25 | 171.6 | 0 | 0 | 801 | 801 |
| Factory 16 | 7 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 17 | 6 | 0.0 | 0 | 0 | 0 | 0 |
| Factory15 | 12 | 357.6 | 284 | 169 | 801 | 632 |
| **Sesquiterpenes** | 92 | 214.4 | 10 | 0 | 4973 | 4973 |
| **Rosin Manufacturers** | 67 | 280.8 | 7 | 0 | 4973 | 4973 |
| Factory 14 | 0 | - | - | - | - | - |
| Factory 11 | 26 | 1.3 | 0.6 | 0 | 8 | 8 |
| Factory 10 | 11 | 1613.0 | 24 | 0 | 4973 | 4973 |
| Factory 13 | 14 | 51.2 | 11 | 2 | 453 | 451 |
| Factory 27 | 14 | 19.8 | 13 | 7 | 53 | 46 |
| Factory 12 | 2 | 21.5 | 22 | 19 | 24 | 5 |
| **Hot Melt Glue Users** | 25 | 36.5 | 39 | 1 | 100 | 99 |
| Factory 16 | 7 | 2.9 | 2 | 1 | 8 | 7 |
| Factory 17 | 6 | 30.0 | 24 | 22 | 55 | 33 |
| Factory 15 | 12 | 59.3 | 53 | 39 | 100 | 61 |

# TABLE 30: Volatile Personal Samples - Summary of Results

| Sample Group | Number of Samples | Volatile Concentrations (µg/m³) | | | | |
|---|---|---|---|---|---|---|
| | | Mean | Median | Minimum | Maximum | Range |
| **α-Pinene** | 80 | 79.5 | 7 | 0 | 809 | 809 |
| **Rosin Manufacturers** | 55 | 31.9 | 1 | 0 | 610 | 610 |
| Factory 14 | 0 | - | - | - | - | - |
| Factory 11 | 24 | 0.4 | 0 | 0 | 5 | 5 |
| Factory 10 | 8 | 135.1 | 2 | 0 | 610 | 610 |
| Factory 13 | 13 | 35.5 | 15 | 0 | 197 | 197 |
| Factory 27 | 8 | 23.4 | 20 | 8 | 50 | 42 |
| Factory 12 | 2 | 8.0 | 8 | 4 | 12 | 8 |
| **Hot Melt Glue Users** | 25 | 184.2 | 53 | 0 | 809 | 809 |
| Factory 16s | 7 | 1.7 | 1 | 0 | 4 | 4 |
| Factory 17 | 6 | 45.0 | 46 | 38 | 53 | 15 |
| Factory 15 | 12 | 360.4 | 266 | 201 | 809 | 608 |
| **β-Pinene** | 82 | 4.3 | 0.4 | 0 | 54 | 54 |
| **Rosin Manufacturers** | 57 | 4.9 | 0.4 | 0 | 54 | 54 |
| Factory 14 | 0 | - | - | - | - | - |
| Factory 11 | 24 | 0.3 | 0 | 0 | 1 | 1 |
| Factory 10 | 8 | 14.0 | 1.5 | 0 | 54 | 54 |
| Factory 13 | 13 | 12.5 | 12 | 9 | 18 | 9 |
| Factory 27 | 10 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 12 | 2 | 0.0 | 0 | 0 | 0 | 0 |
| **Hot Melt Glue Users** | 25 | 3.0 | 3 | 0 | 10 | 10 |
| Factory 16 | 7 | 3.6 | 3 | 3 | 5 | 2 |
| Factory 17 | 6 | 8.2 | 9 | 5 | 10 | 5 |
| Factory 15 | 12 | 0.0 | 0 | 0 | 0 | 0 |
| **Limonene** | 82 | 52.9 | 0 | 0 | 801 | 801 |
| **Rosin Manufacturers** | 57 | 0.9 | 0 | 0 | 32 | 32 |
| Factory 14 | 0 | - | - | - | - | - |
| Factory 11p | 24 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 10 | 8 | 6.5 | 0 | 0 | 32 | 32 |
| Factory 13 | 13 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 27 | 10 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 12 | 2 | 0.0 | 0 | 0 | 0 | 0 |
| **Hot Melt Glue Users** | 25 | 171.6 | 0 | 0 | 801 | 801 |
| Factory 16 | 7 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 17 | 6 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 15 | 12 | 357.6 | 284 | 169 | 801 | 632 |
| **Sesquiterpenes** | 82 | 142.2 | 7 | 0 | 4973 | 4973 |
| **Rosin Manufacturers** | 57 | 188.5 | 5 | 0 | 4973 | 4973 |
| Factory 14 | 0 | - | - | - | - | - |
| Factory 11 | 24 | 1.4 | 0.6 | 0 | 8 | 8 |
| Factory 10 | 8 | 1228.1 | 5 | 0 | 4973 | 4973 |
| Factory 13 | 13 | 53.5 | 11 | 2 | 453 | 451 |
| Factory 27 | 10 | 15.0 | 11 | 7 | 53 | 46 |
| Factory 12 | 2 | 21.5 | 22 | 19 | 24 | 5 |
| **Hot Melt Glue Users** | 25 | 36.5 | 39 | 1 | 100 | 99 |
| Factory 16 | 7 | 2.9 | 2 | 1 | 8 | 7 |
| Factory 17 | 6 | 30.0 | 24 | 22 | 55 | 33 |
| Factory 15 | 12 | 59.3 | 53 | 39 | 100 | 61 |

## TABLE 31: Volatile Static Samples - Summary of Results

| Sample Group | Number of Samples | Volatile Concentrations (µg/m³) | | | | |
|---|---|---|---|---|---|---|
| | | Mean | Median | Minimum | Maximum | Range |
| **α-Pinene** | 10 | 84.3 | 35 | 0 | 390 | 390 |
| **Rosin Manufacturers** | 10 | 84.3 | 35 | 0 | 390 | 390 |
| Factory 14 | 0 | - | - | - | - | - |
| Factory 11 | 2 | 0.2 | 0 | 0 | 0.3 | 0.3 |
| Factory 10 | 3 | 238.7 | 256 | 70 | 390 | 320 |
| Factory 13 | 1 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 27 | 4 | 31.8 | 35 | 21 | 37 | 16 |
| Factory 12 | 0 | - | - | - | - | - |
| **β-Pinene** | 10 | 16.9 | 0 | 0 | 80 | 80 |
| **Rosin Manufacturers** | 10 | 16.9 | 0 | 0 | 80 | 80 |
| Factory 14 | 0 | - | - | - | - | - |
| Factory 11 | 2 | 0.3 | 0 | 0 | 0.6 | 0.6 |
| Factory 10 | 3 | 52.0 | 51 | 25 | 80 | 55 |
| Factory 13 | 1 | 12.0 | 12 | 12 | 12 | 0 |
| Factory 27 | 4 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 12 | 0 | - | - | - | - | - |
| **Limonene** | 10 | 4.4 | 0 | 0 | 31 | 31 |
| **Rosin Manufacturers** | 10 | 4.4 | 0 | 0 | 31 | 31 |
| Factory 14 | 0 | - | - | - | - | - |
| Factory 11 | 2 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 10 | 3 | 14.7 | 9 | 4 | 31 | 27 |
| Factory 13 | 1 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 27 | 4 | 0.0 | 0 | 0 | 0 | 0 |
| Factory 12 | 0 | - | - | - | - | - |
| **Sesquiterpenes** | 10 | 806.7 | 29 | 0 | 4455 | 4455 |
| **Rosin Manufacturers** | 10 | 806.7 | 29 | 0 | 4455 | 4455 |
| Factory 14 | 0 | - | - | - | - | - |
| Factory 11 | 2 | 0.4 | 0.4 | 0 | 0.8 | 0.8 |
| Factory 10 | 3 | 2639.3 | 2646 | 817 | 4455 | 3638 |
| Factory 13 | 1 | 21.0 | 21 | 21 | 21 | 0 |
| Factory 27 | 4 | 29.3 | 29 | 18 | 52 | 34 |
| Factory 12 | 0 | - | - | - | - | - |

## TABLE 32a: Volatile Samples - Distribution of Results

| Sample Group | Volatile Terpene | No. of Samples | Volatile Concentrations (µg/m³) | | | |
|---|---|---|---|---|---|---|
| | | | < 10 µg/m³ | 10 - 100 µg/m³ | 100 - 1000 µg/m³ | > 1000 µg/m³ |
| **All Samples** | α-Pinene | 90 | 45 | 28 | 17 | - |
| | β-Pinene | 92 | 72 | 20 | - | - |
| | Limonene | 92 | 77 | 3 | 12 | - |
| | Sesquiterpenes | 92 | 46 | 38 | 4 | 4 |
| **Rosin Manufacturers** | α-Pinene | 65 | 38 | 22 | 5 | - |
| | β-Pinene | 67 | 49 | 18 | - | - |
| | Limonene | 67 | 64 | 3 | - | - |
| | Sesquiterpenes | 67 | 39 | 21 | 3 | 4 |
| **Hot Melt Glue Users** | α-Pinene | 25 | 7 | 6 | 12 | - |
| | β-Pinene | 25 | 23 | 2 | - | - |
| | Limonene | 25 | 13 | - | 12 | - |
| | Sesquiterpenes | 25 | 7 | 17 | 1 | - |

## TABLE 32b: Volatile Samples - Distribution of Results

| Sample Group | Volatile Terpene | No. of Samples | Volatile Concentrations (µg/m³) | | | |
|---|---|---|---|---|---|---|
| | | | < 10 µg/m³ | 10 - 100 µg/m³ | 100 - 1000 µg/m³ | > 1000 µg/m³ |
| Personal Samples | α-Pinene | 80 | 42 | 23 | 15 | - |
| | β-Pinene | 82 | 66 | 16 | - | - |
| | Limonene | 82 | 68 | 2 | 12 | - |
| | Sesquiterpenes | 82 | 44 | 33 | 3 | 2 |
| Rosin Manufacturers | α-Pinene | 55 | 35 | 17 | 3 | - |
| | β-Pinene | 57 | 43 | 14 | - | - |
| | Limonene | 57 | 55 | 2 | - | - |
| | Sesquiterpenes | 57 | 37 | 16 | 2 | 2 |
| Hot Melt Glue Users | α-Pinene | 25 | 7 | 6 | 12 | - |
| | β-Pinene | 25 | 23 | 2 | - | - |
| | Limonene | 25 | 13 | - | 12 | - |
| | Sesquiterpenes | 25 | 7 | 17 | 1 | - |
| Static Samples | α-Pinene | 10 | 3 | 5 | 2 | - |
| | β-Pinene | 10 | 6 | 4 | - | - |
| | Limonene | 10 | 9 | 1 | - | - |
| | Sesquiterpenes | 10 | 2 | 5 | 1 | 2 |
| Rosin Manufacturers | α-Pinene | 10 | 3 | 5 | 2 | - |
| | β-Pinene | 10 | 6 | 4 | - | - |
| | Limonene | 10 | 9 | 1 | - | - |
| | Sesquiterpenes | 10 | 2 | 5 | 1 | 2 |
| Hot Melt Glue Users | α-Pinene | 0 | - | - | - | - |
| | β-Pinene | 0 | - | - | - | - |
| | Limonene | 0 | - | - | - | - |
| | Sesquiterpenes | 0 | - | - | - | - |

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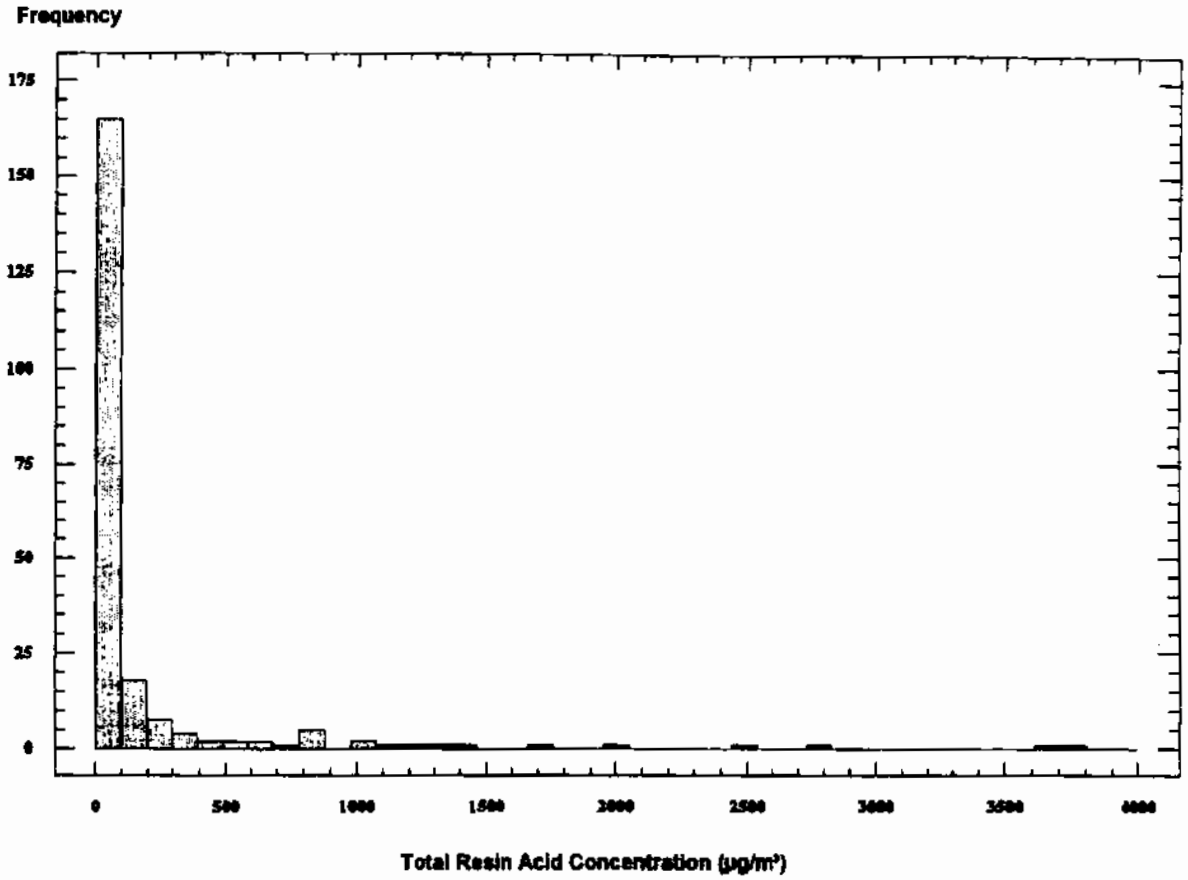
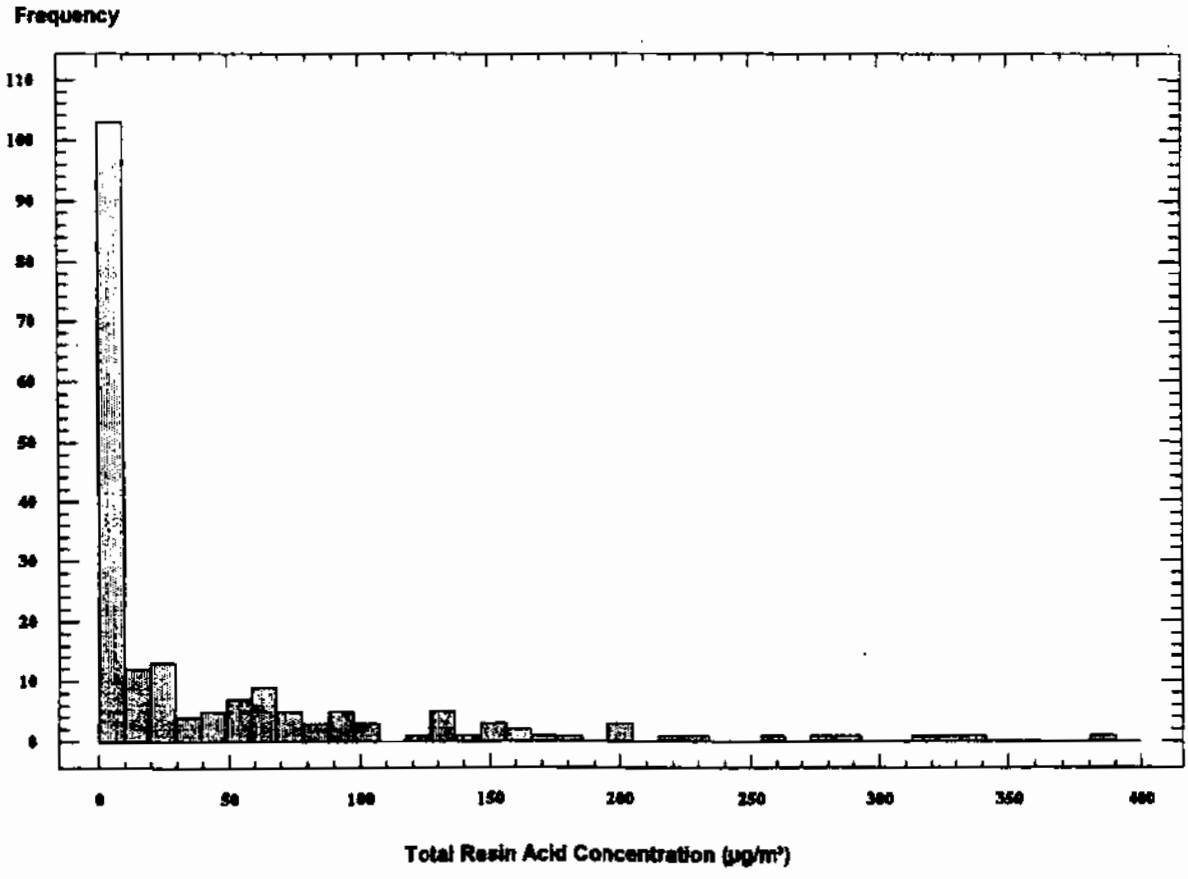
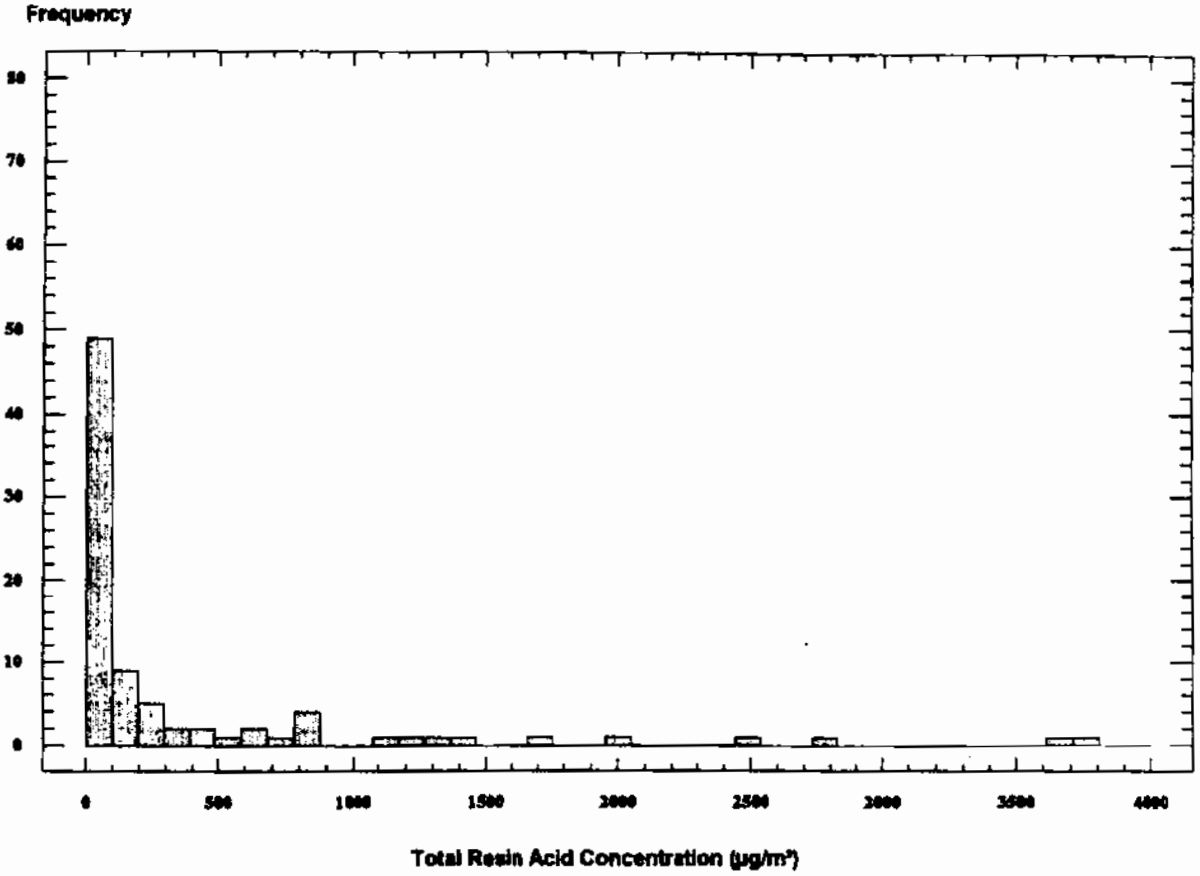
## FIGURE 1a: TRA Concentrations (All Sample Types)



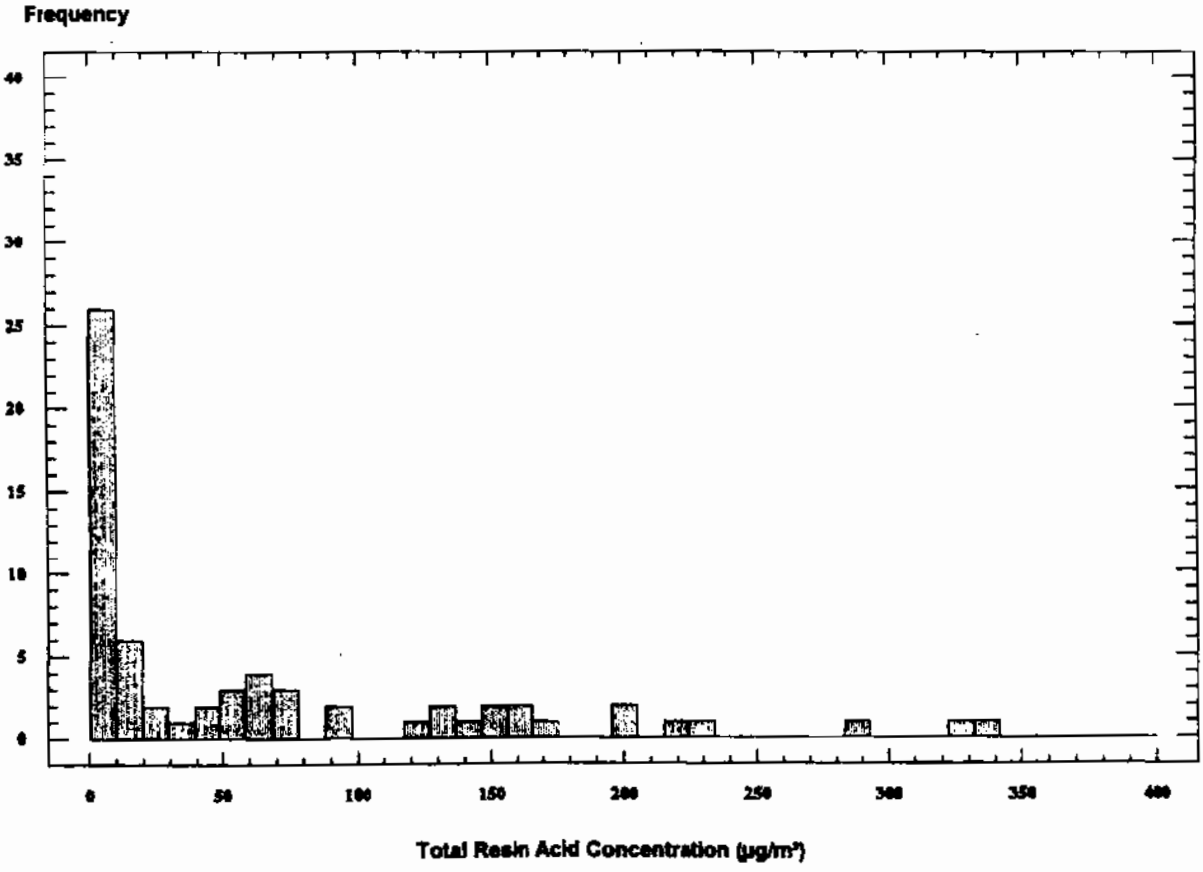

## FIGURE 1b: TRA Concentrations (All Sample Types)



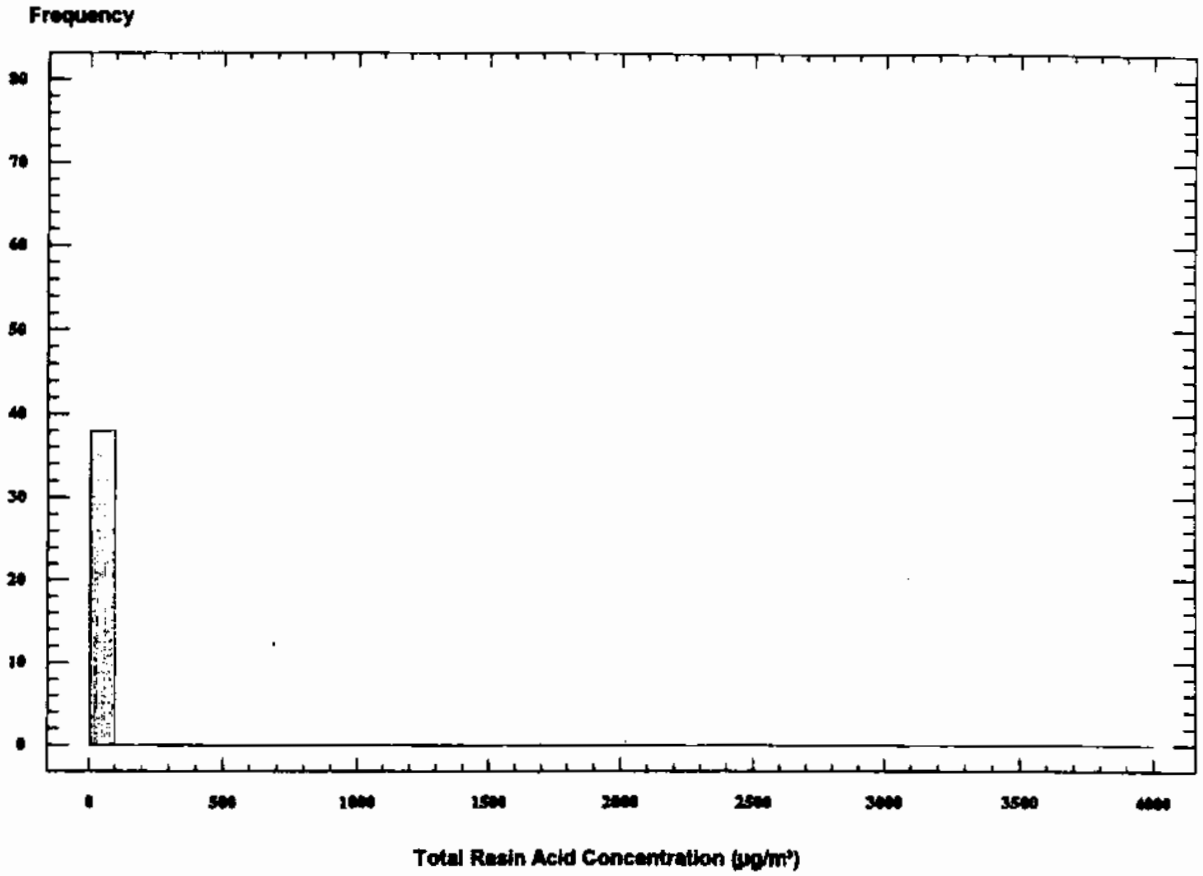
## FIGURE 2a: TRA Concentrations (Rosin Manufacturers)



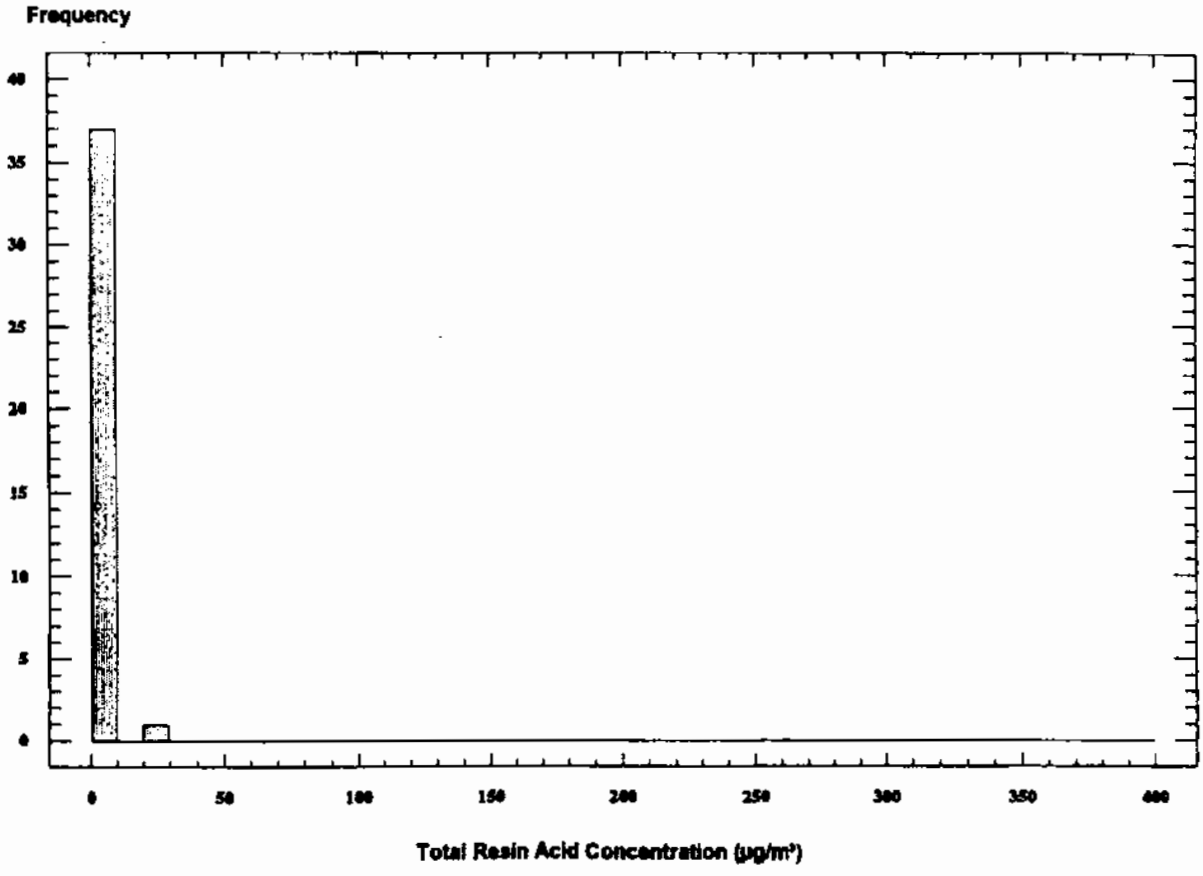

## FIGURE 2b: TRA Concentrations (Rosin Manufacturers)



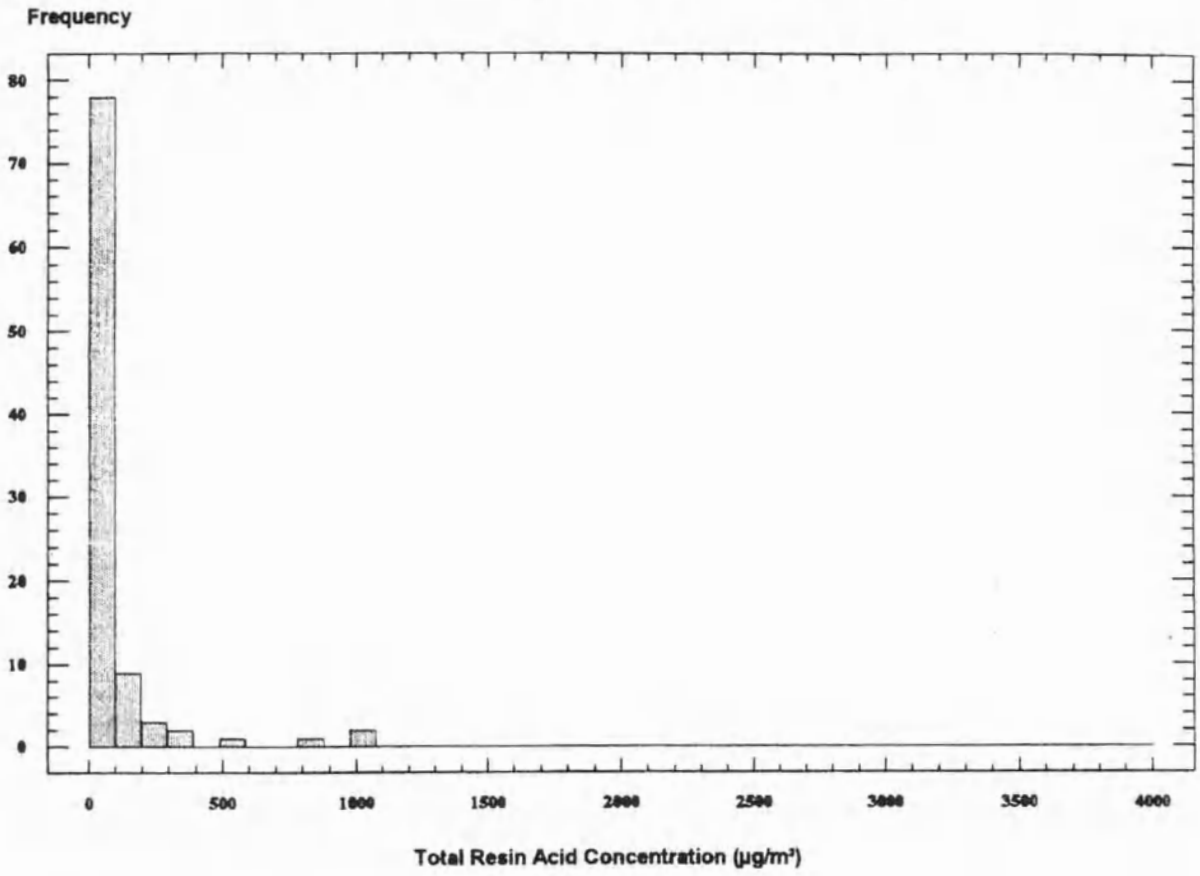
## FIGURE 3a: TRA Concentrations (Hot Melt Glue Users)



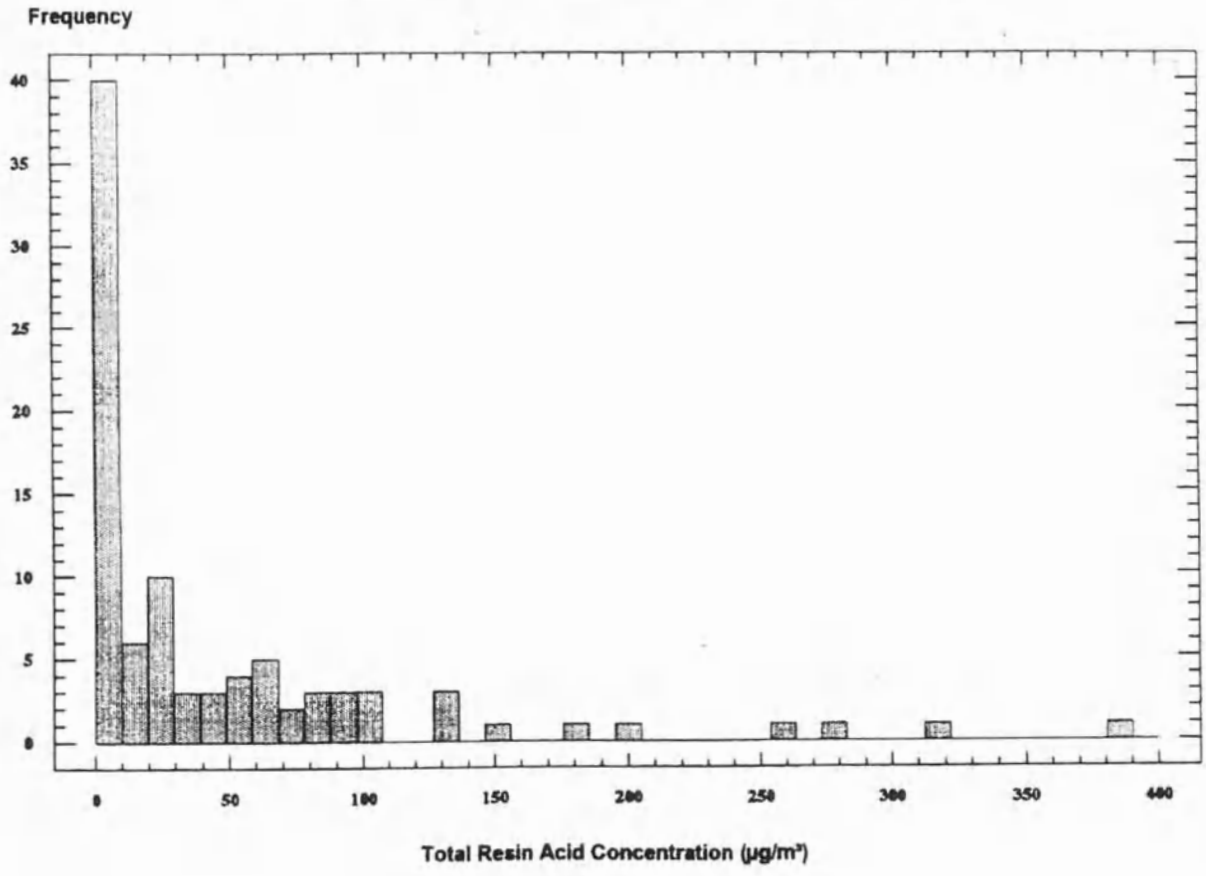

## FIGURE 3b: TRA Concentrations (Hot Melt Glue Users)



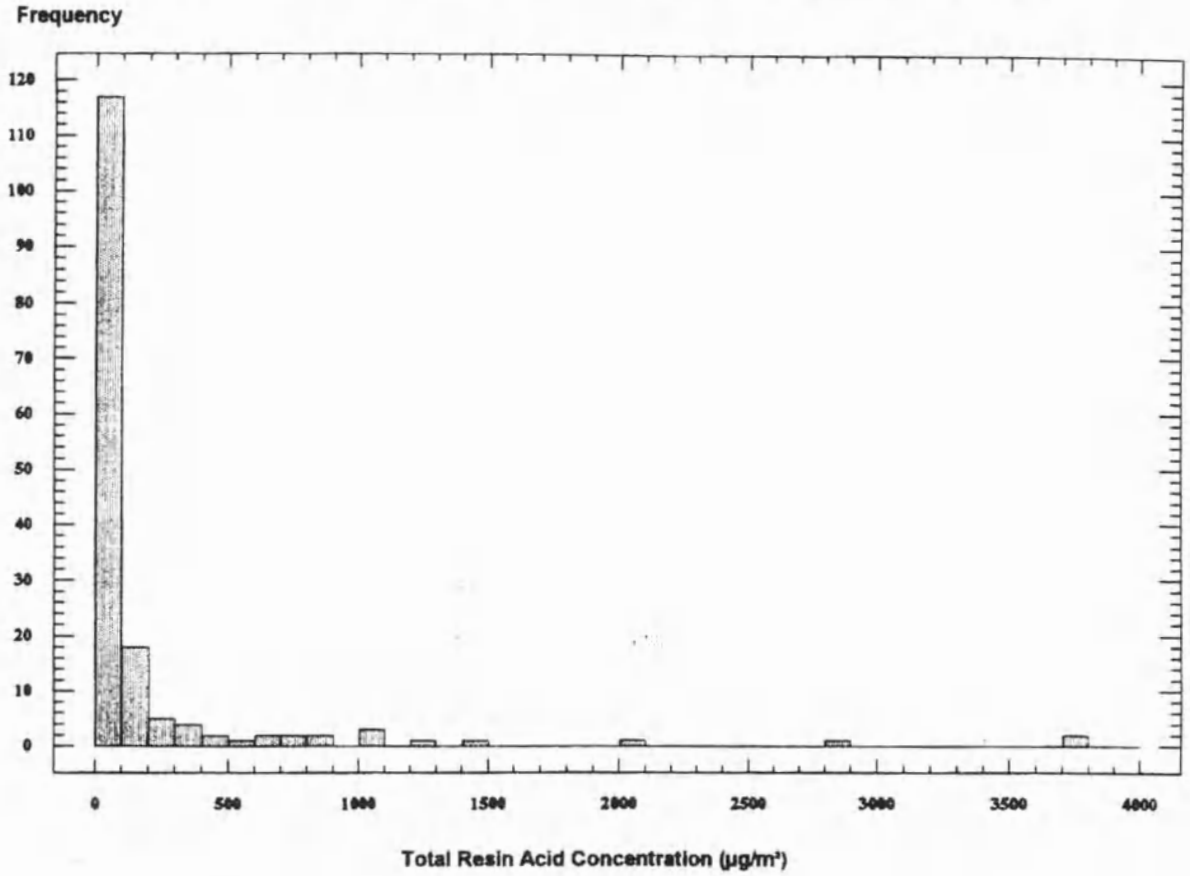
## FIGURE 4a: TRA Concentrations (Solderers)




## FIGURE 4b: TRA Concentrations (Solderers)



## FIGURE 5a: Total Resin Acid Concentrations (Personal Samples)




## FIGURE 5b: TRA Concentrations (Personal Samples)

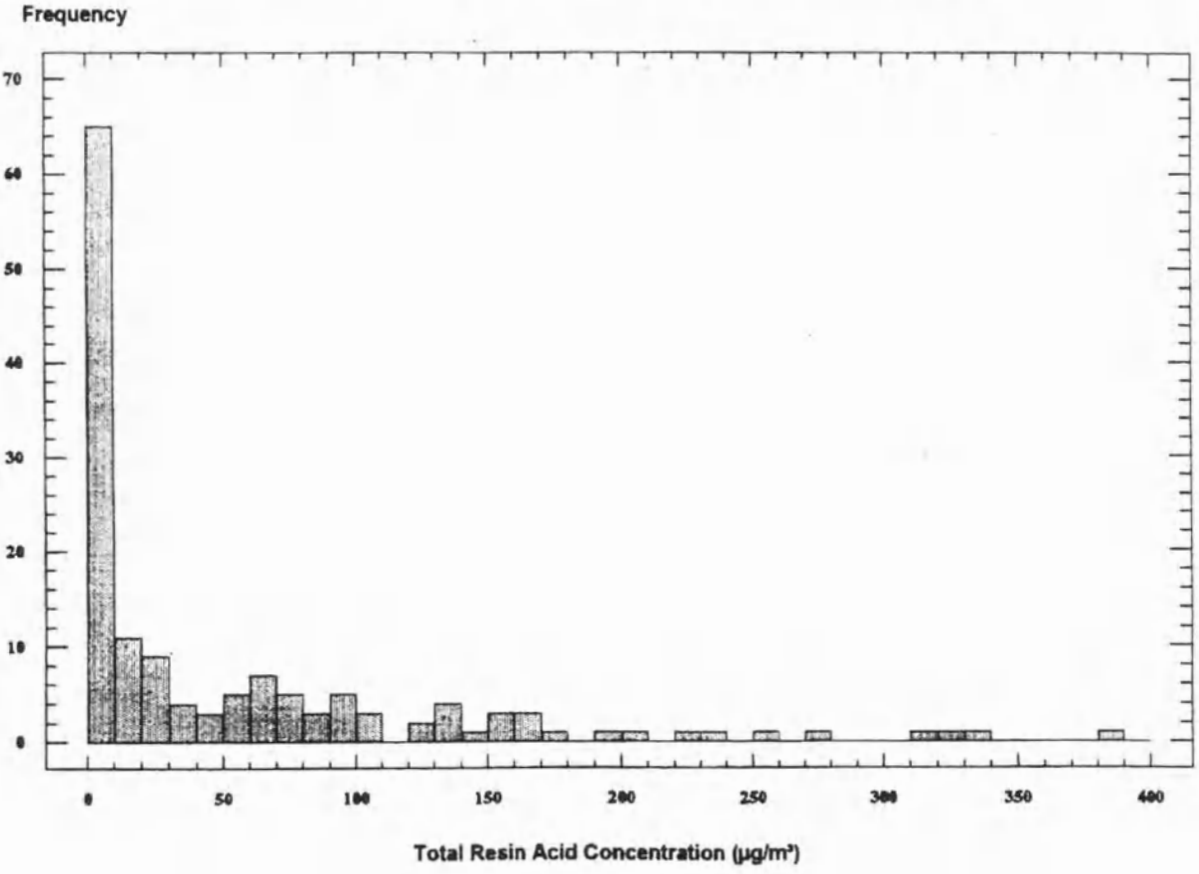


FIGURE 6a: TRA Concentrations (Personal Samples - Rosin Manufacturers)

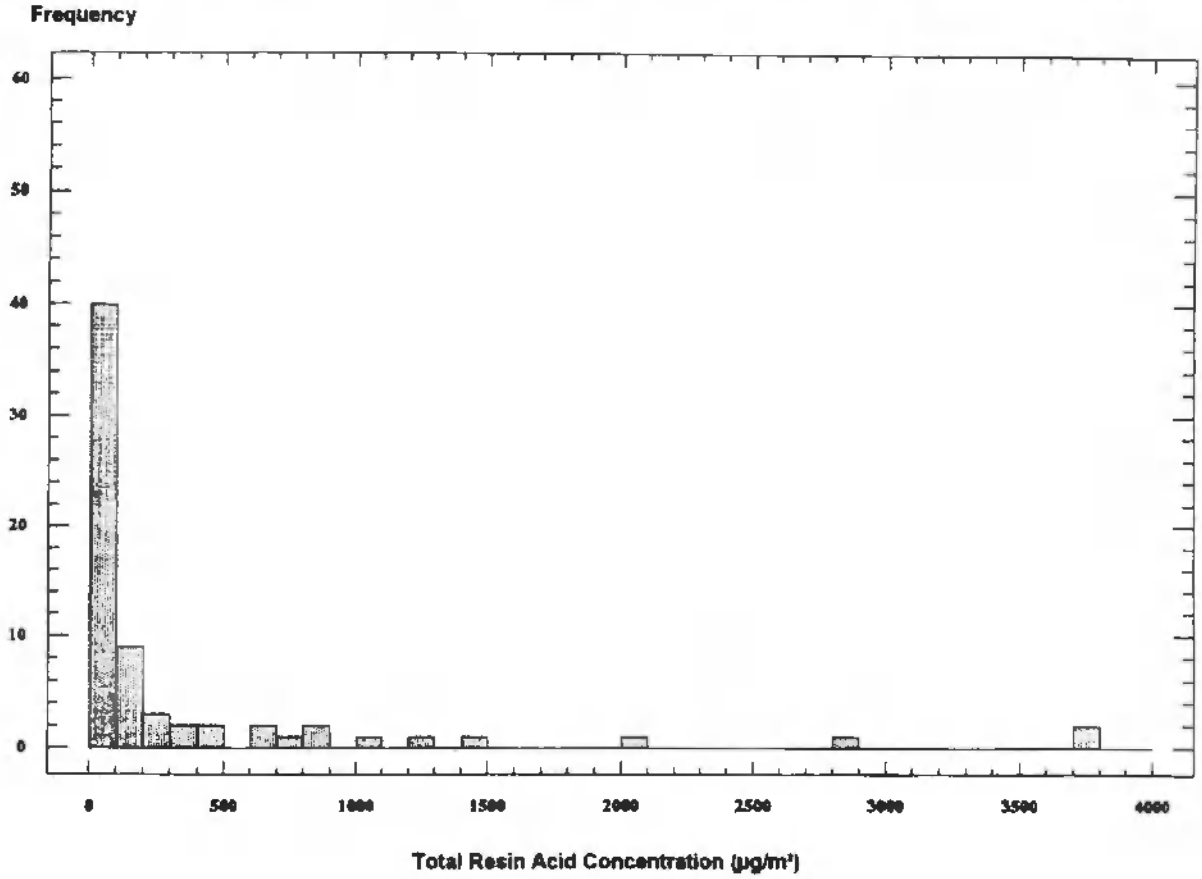



FIGURE 6b: TRA Concentrations (Personal Samples - Rosin Manufacturers)

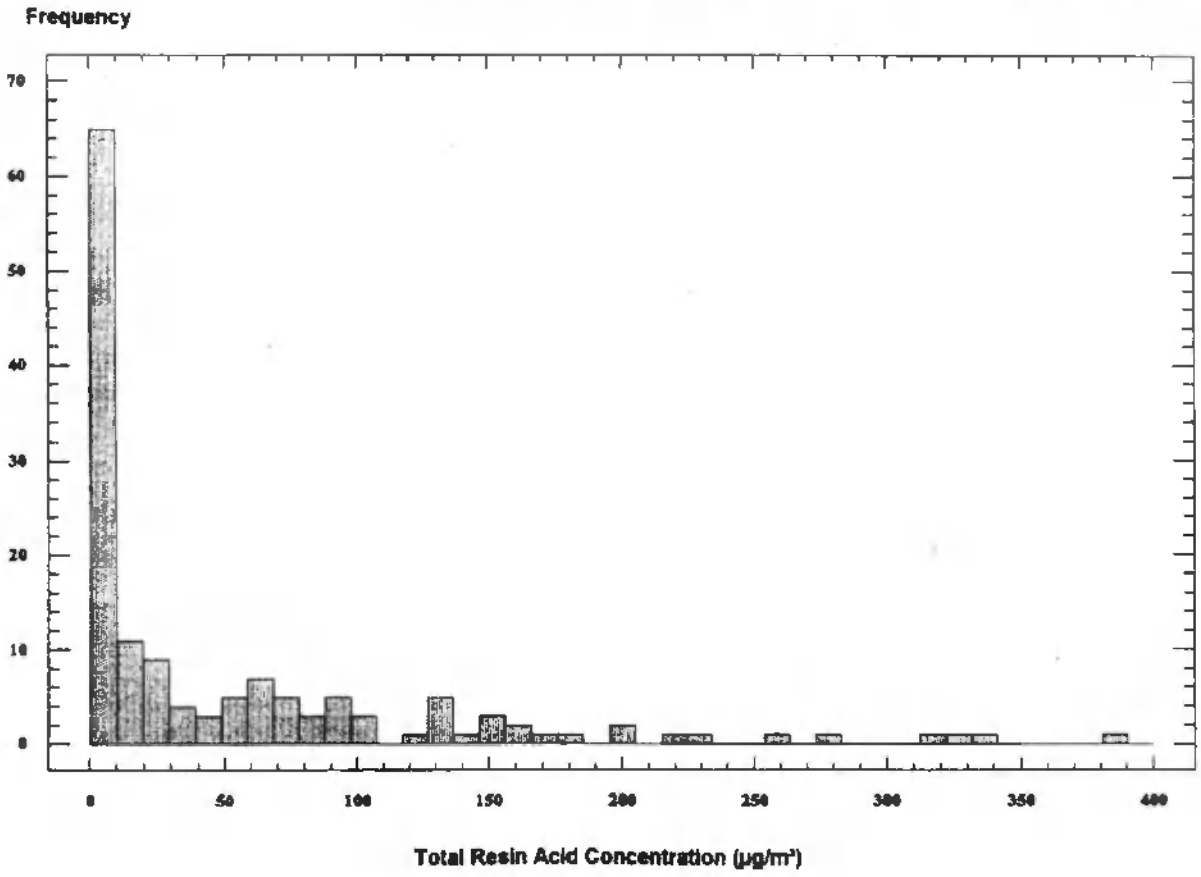


**FIGURE 7a: TRA Concentrations (Personal Samples - Hot Melt Glue Users)**

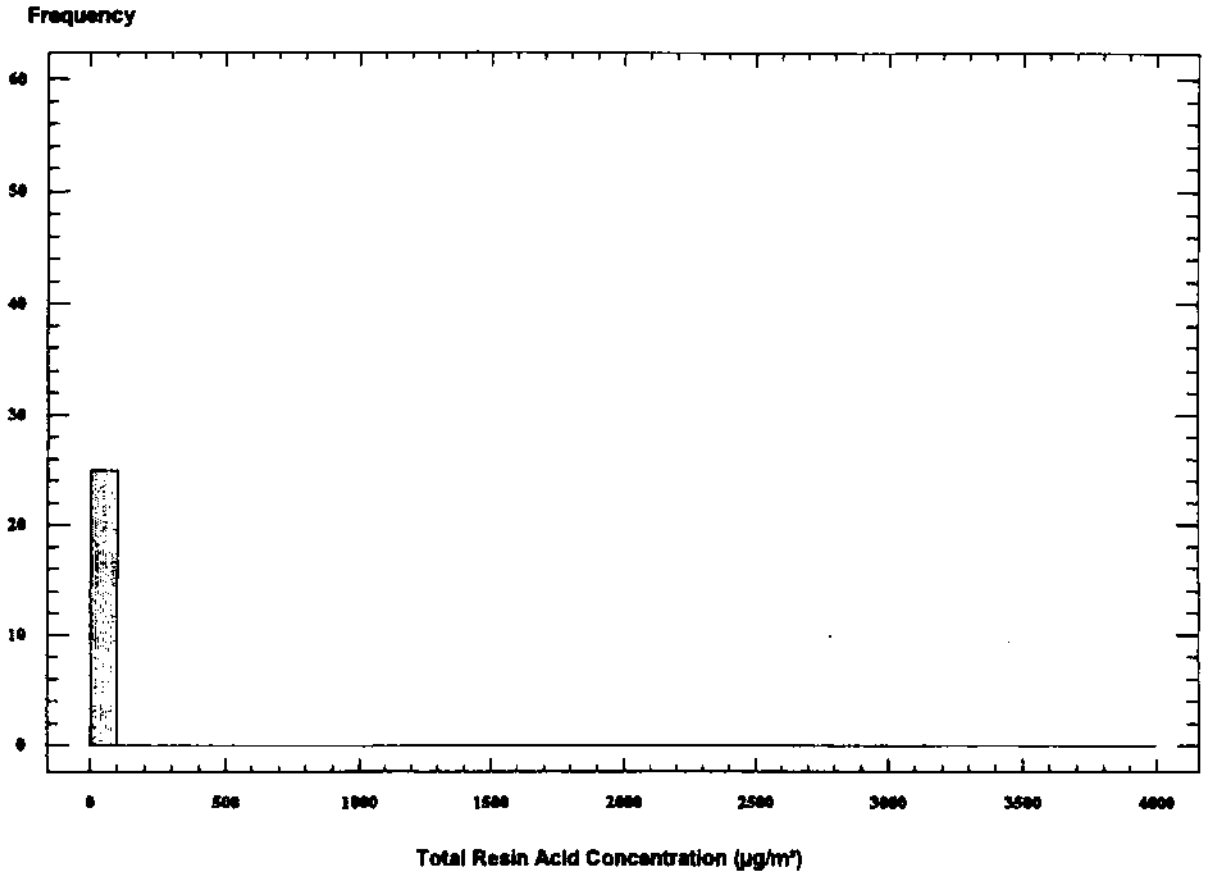
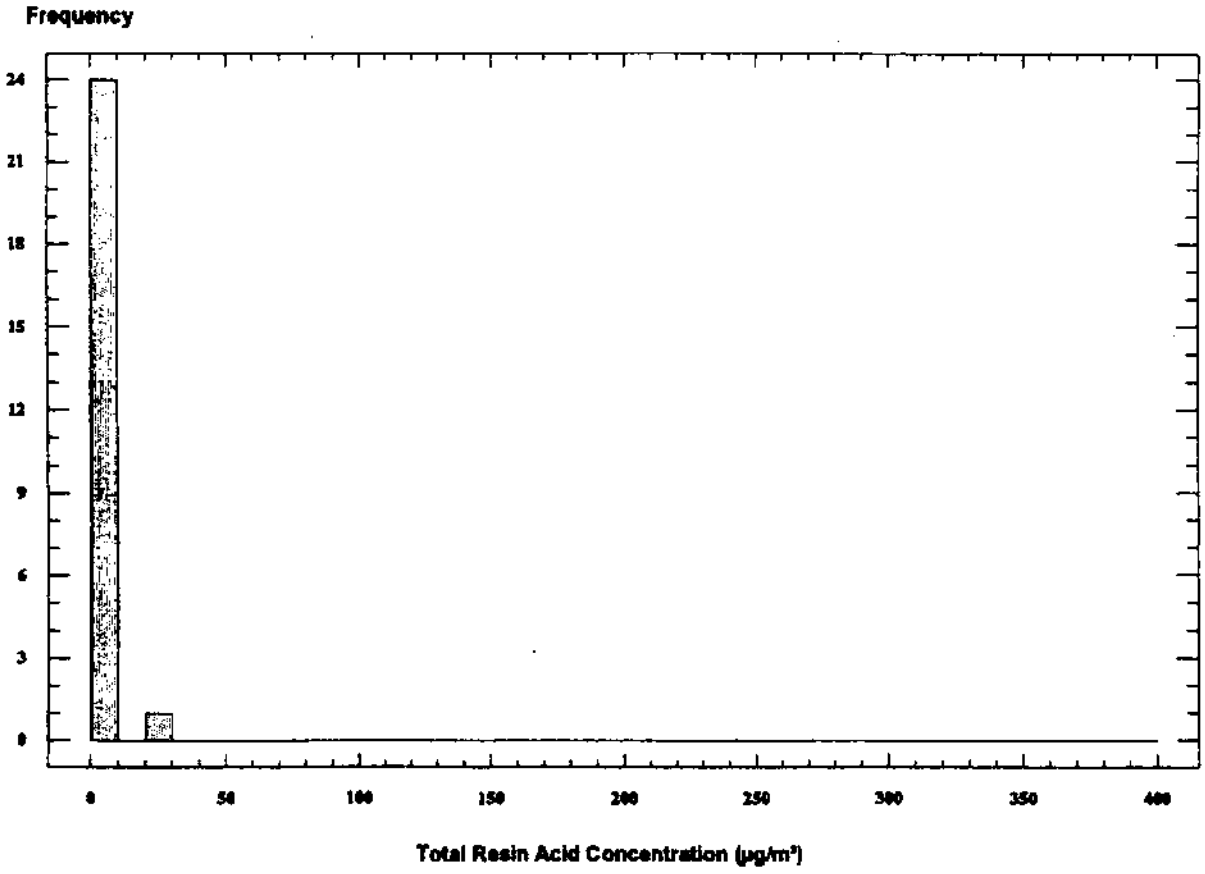
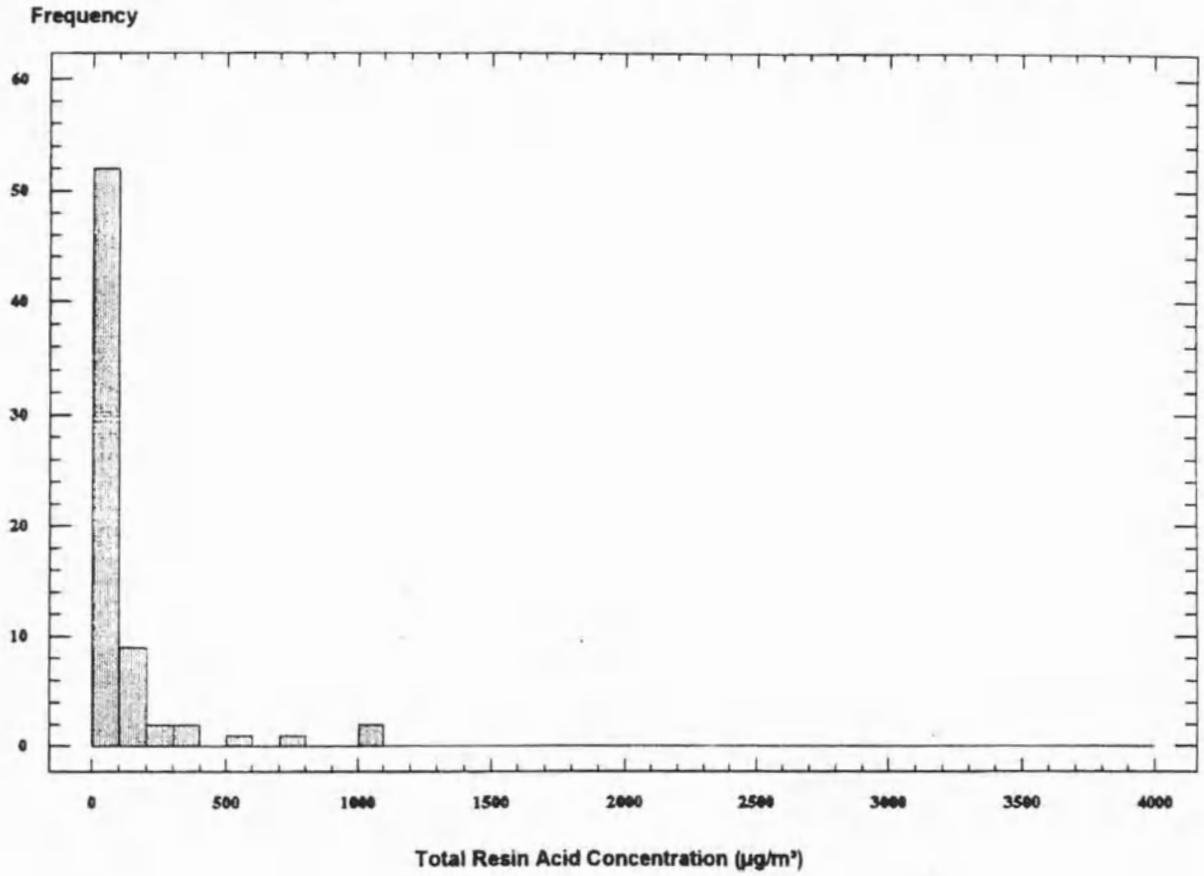


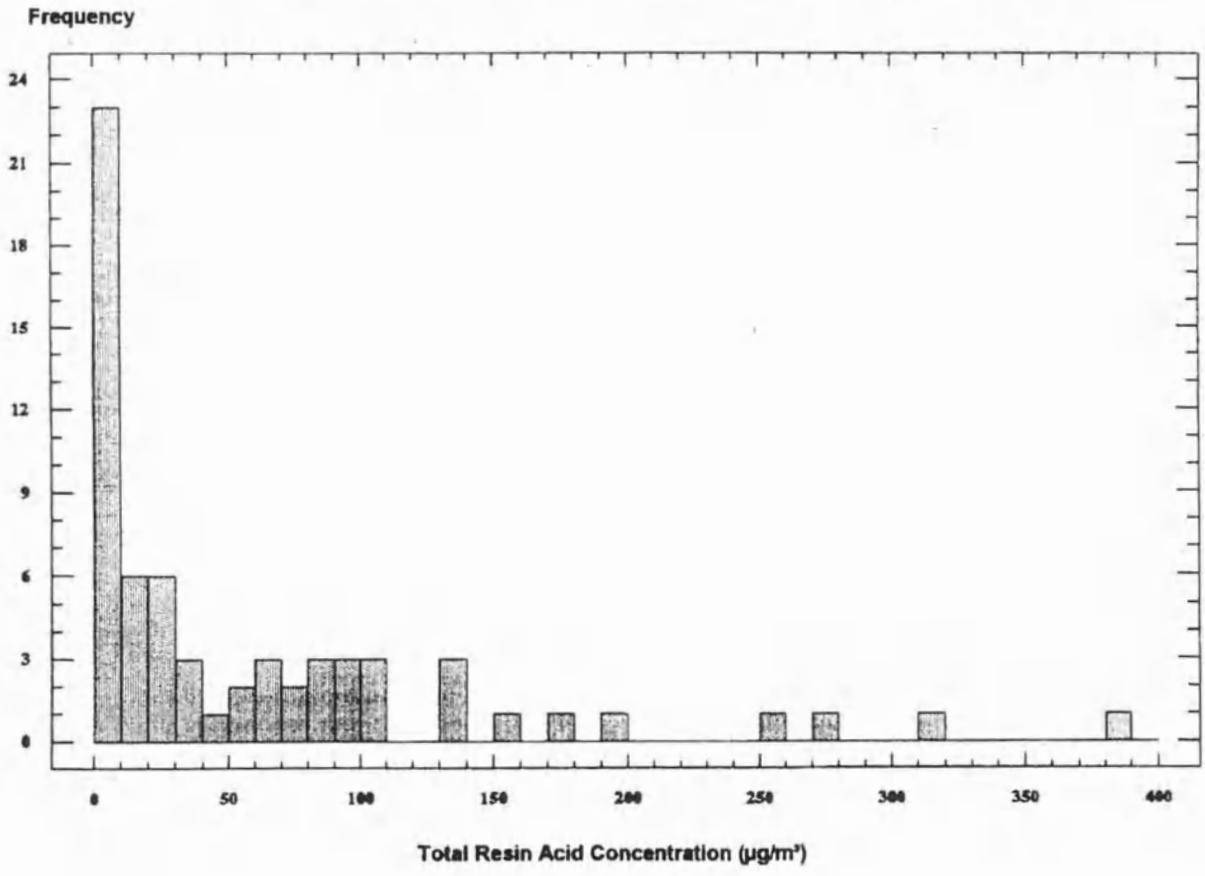

**FIGURE 7b: TRA Concentrations (Personal Samples - Hot Melt Glue Users)**



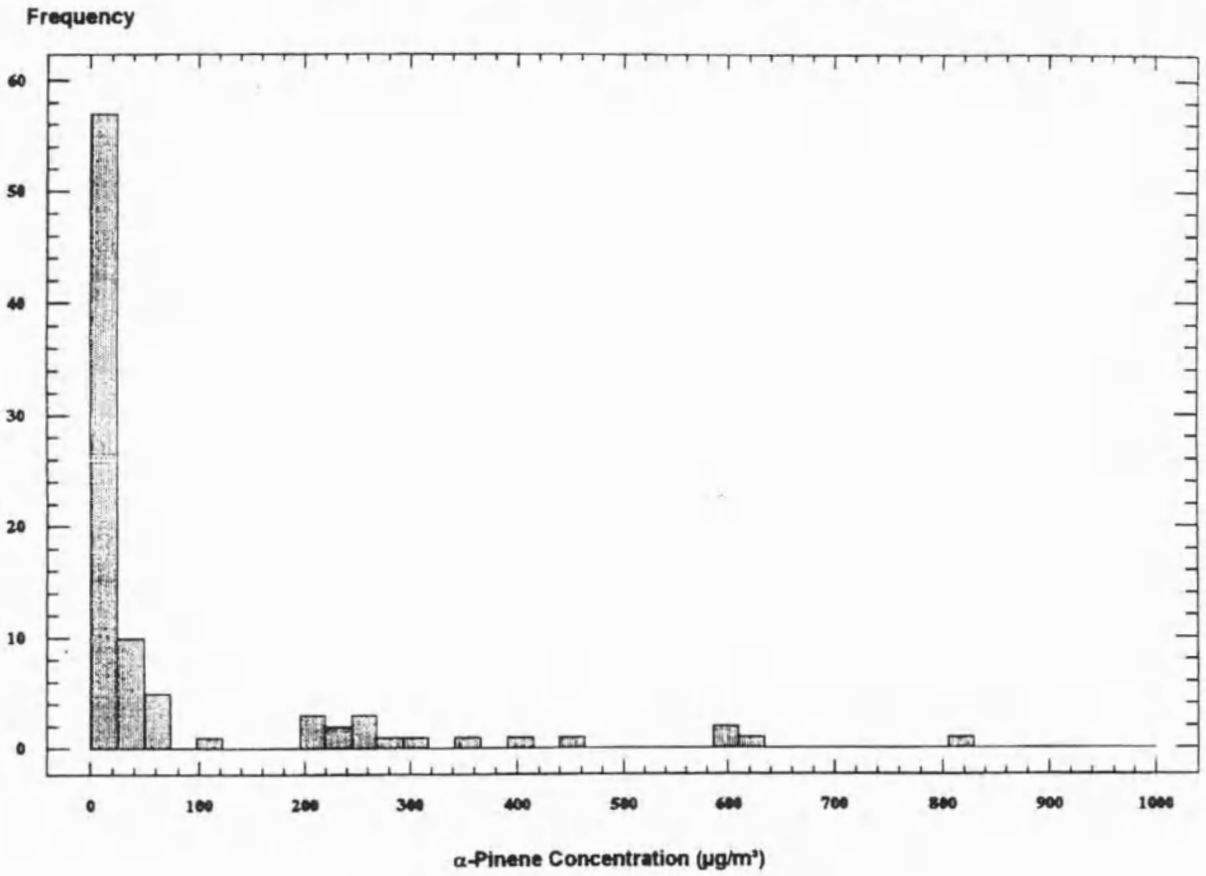
## FIGURE 8a: TRA Concentrations (Personal Samples - Solderers)



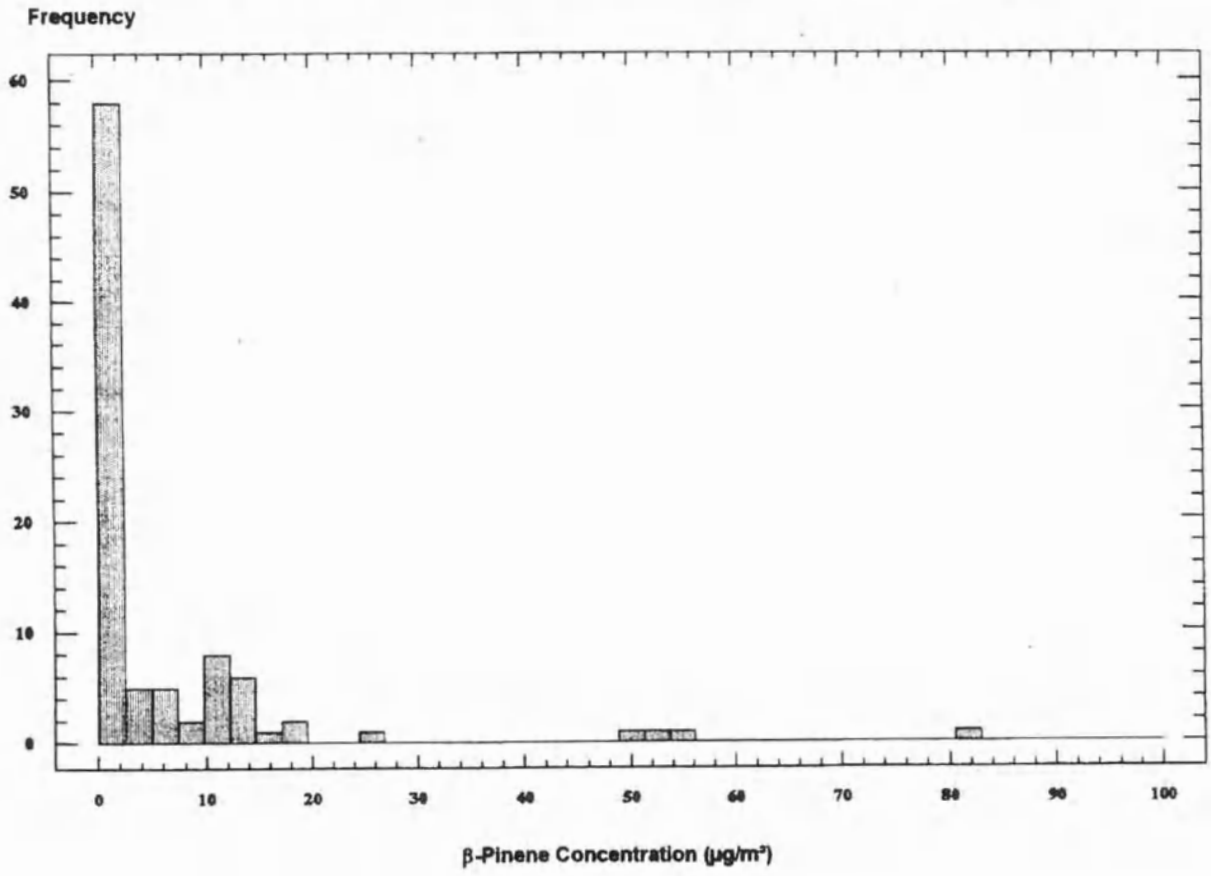

## FIGURE 8b: TRA Concentrations (Personal Samples - Solderers)



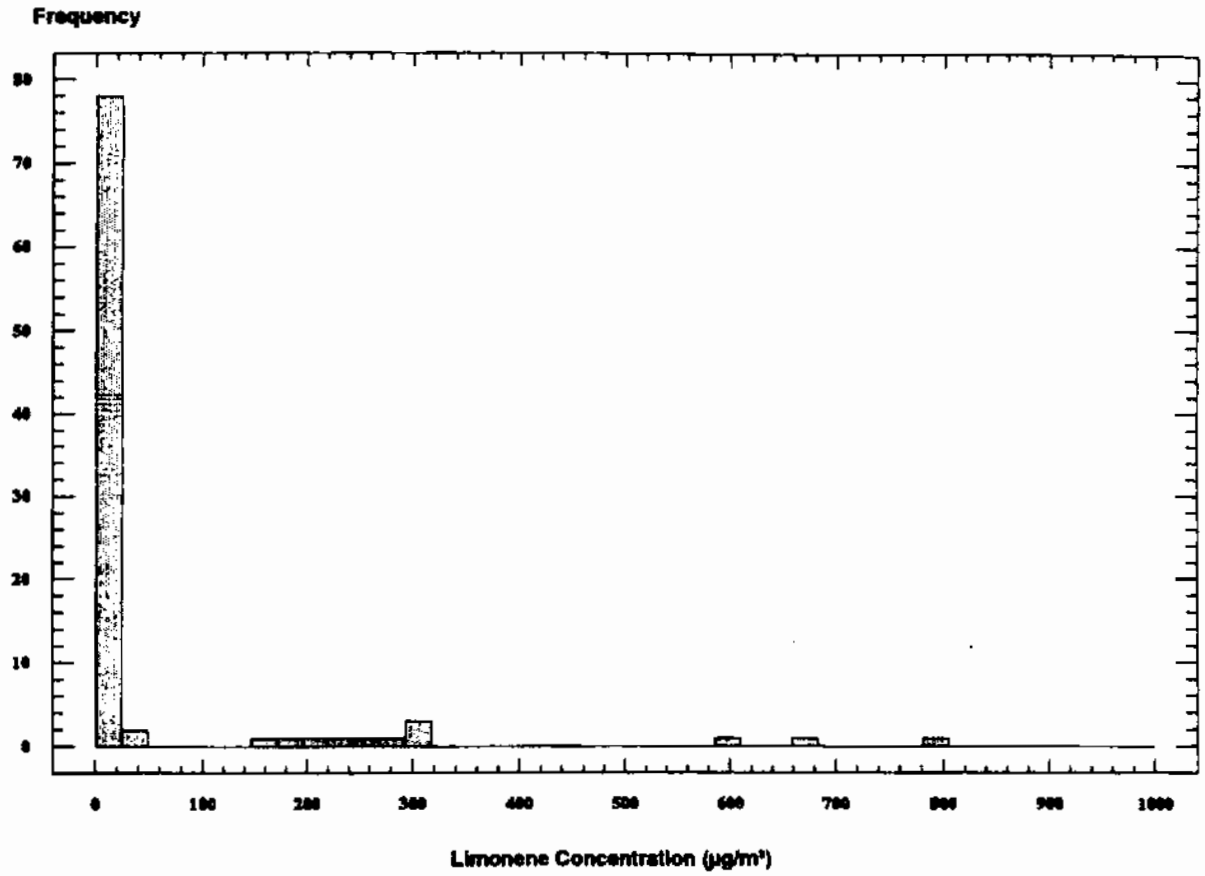
## FIGURE 9: α-Pinene Concentrations (All Samples)



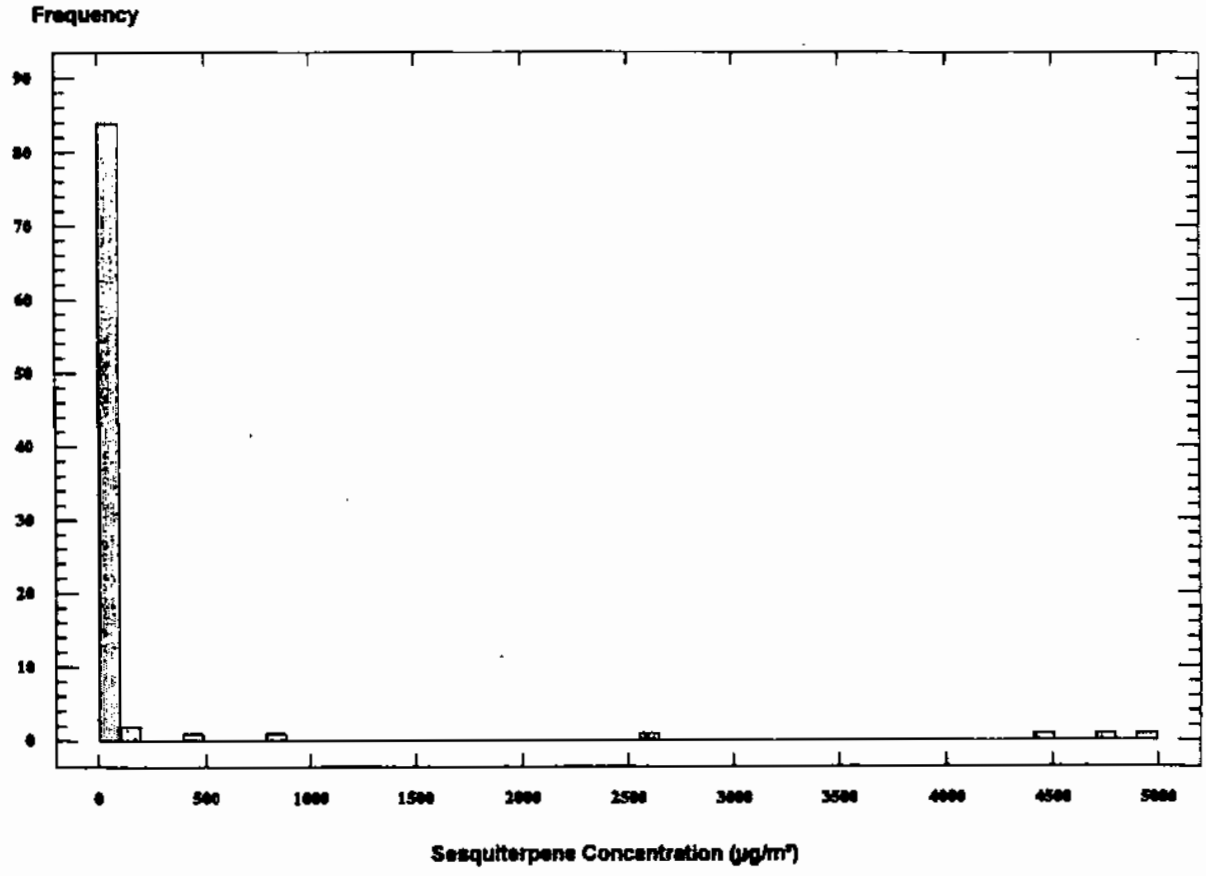

## FIGURE 10: β-Pinene Concentrations (All Samples)



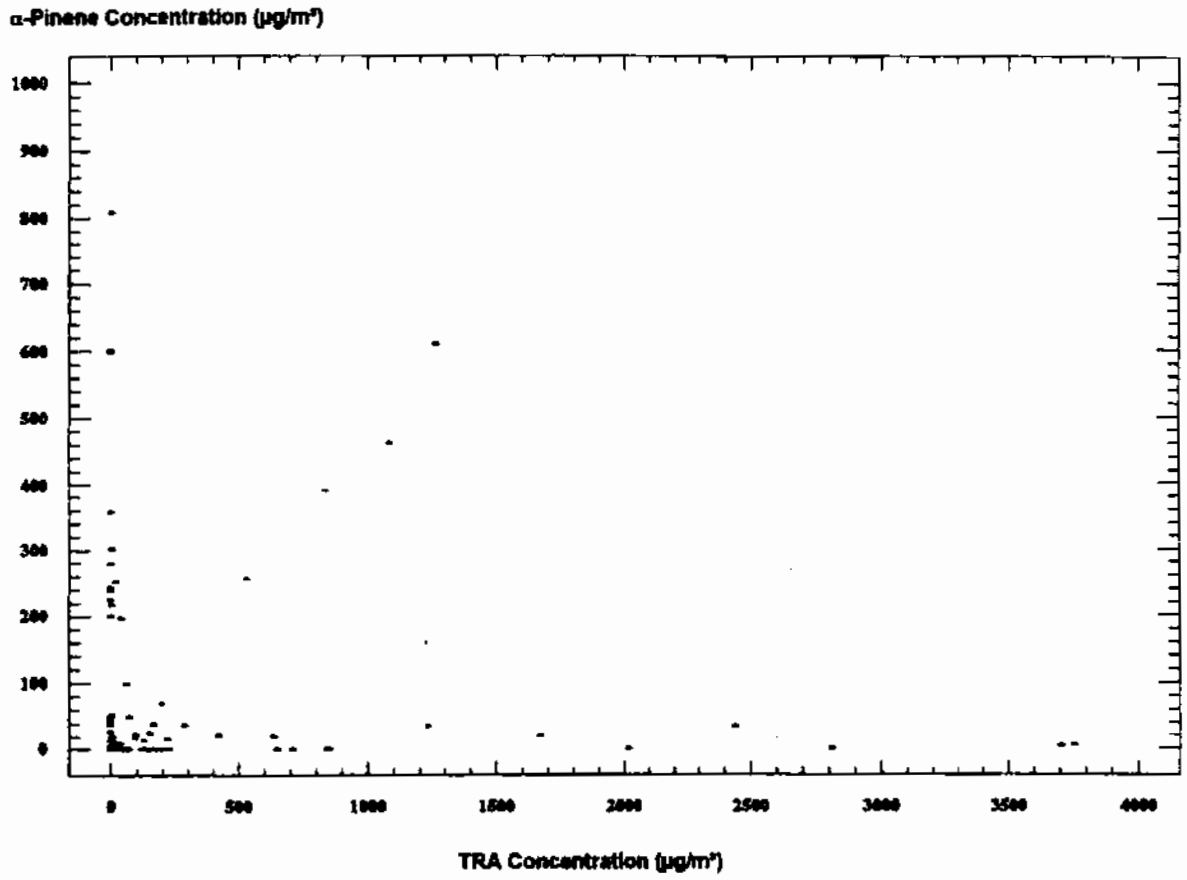
## FIGURE 11: Limonene Concentrations (All Samples)



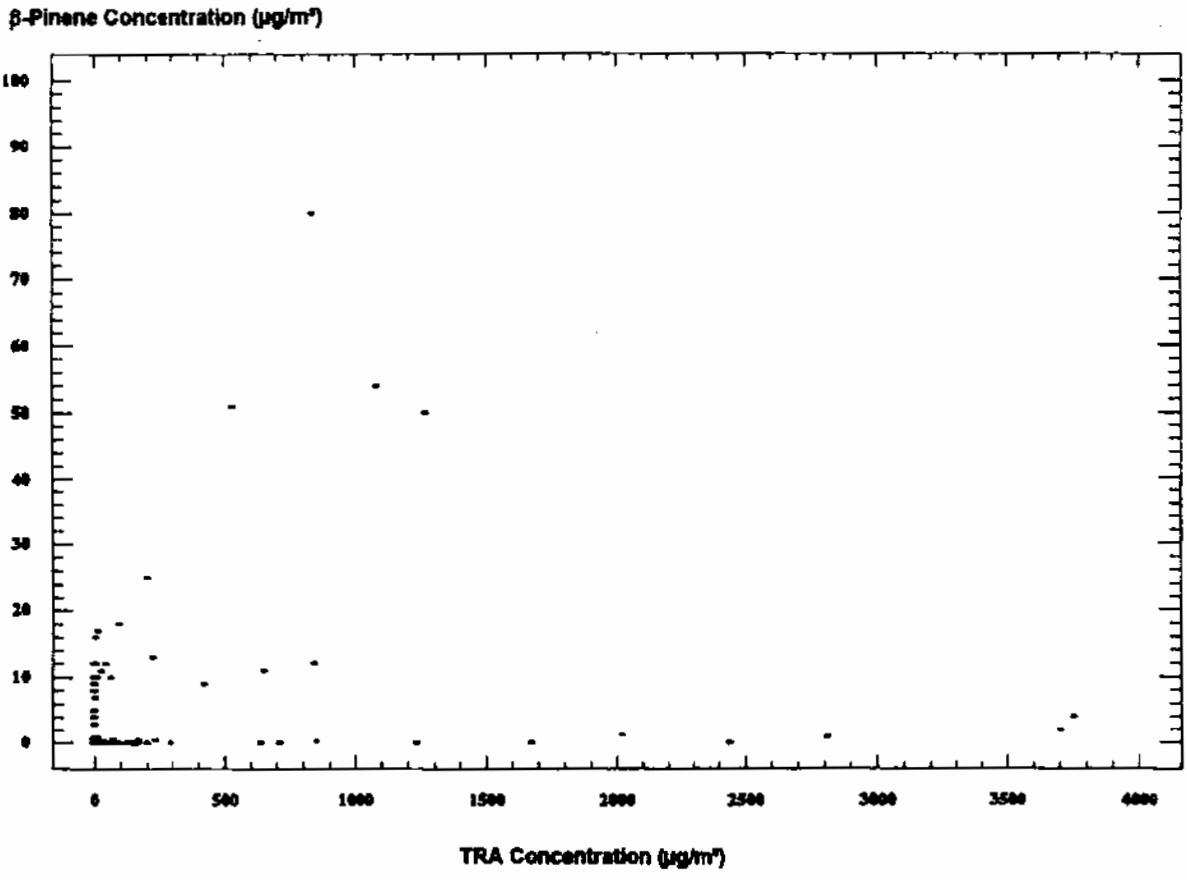

## FIGURE 12: Sesquiterpene Concentrations (All Samples)



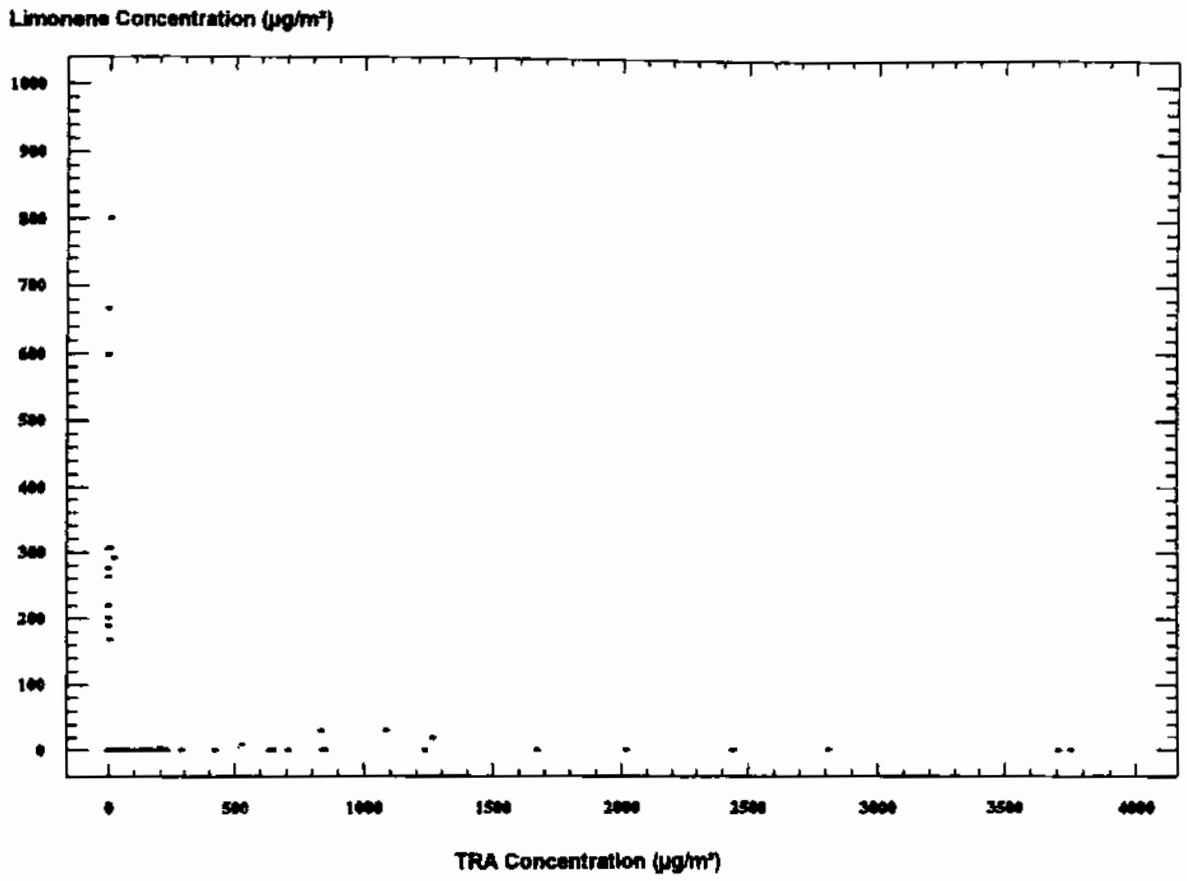
## FIGURE 13: α-Pinene versus TRA Concentration (All Samples)




## FIGURE 14: β-Pinene versus TRA Concentration (All Samples)



## FIGURE 15: Limonene versus TRA Concentration (All Samples)




## FIGURE 16: Sesquiterpene versus TRA Concentration (All Samples)