Evaluation of the Temperatures Attained by Electronic Components During Various Manual Soldering Operations

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ABSTRACT—Component-failure analyses showed that defective spacecraft devices had been overheated during soldering operations. Problems were traced to ESA contractors' sites, and it was verified that Quality Assurance personnel had omitted to control pretinning-bath and soldering-iron temperatures. In the present study, a large quantity of data has been acquired under controlled processing conditions. The rises in temperature of components were recorded during degolding, pretinning, soldering and the reworking of soldered joints. These records will assist future component-failure review boards.

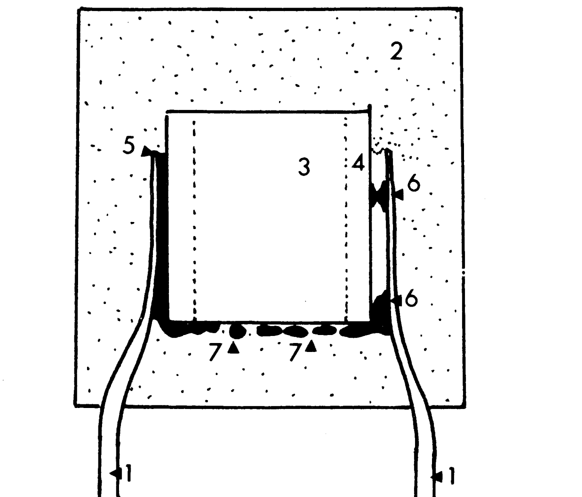
The existing ESA soldering specifications for manual soldering and repair, if adhered to, ensure that the maximum temperature ratings ascribed to standard spacecraft components will not be exceeded.

The application of heat sinks to certain delicate components during degolding has been found essential, and it may occasionally be found advantageous to apply them also during pretinning and other soldering operations. This paper is based on a European Space Agency Report, ESA STM–230.

INTRODUCTION

Various soldering aids may be used during the assembly of components on printed circuit boards. Among the most important are those known as heat sinks. These devices clip on to the leads of components and prevent heat from reaching temperature-sensitive areas such as glass-to-metal seals, low melting point joints within a component and the delicate silicon wafers that support integrated circuits. The components that sustained the most extensive damage during soldering operations performed by ESA contractors working on spacecraft projects were ceramic capacitors. The problem areas are illustrated in Figure 1, and the problems they give rise to are:

(i) *Open circuits* due to total lead separations and inadequate lead bonding;
(ii) *Short circuits* due to solder reflow and contamination by solder particles between the electrodes.



1 Gold plated nickel, or tin plate copper lead.
2 Mouldable plastic encapsulant.
3 Ceramic plates supporting conductors.
4 Silver metallisation.
5 Internal solder, typically low melting point silver-loaded tin-lead alloy.
6 Intermittent solder joint; at high temperature plastic expands causing open.
7 Short circuit follows interconnecting balls of re-flowed solder.

Fig. 1 *Schematic diagram showing typical failure modes of ceramic capacitors.*

The failure modes of these capacitors—like those of several other types of component—are associated with excessive temperatures that cause melting of small soldered joints within the component packages. Experience gained from performing component-failure analyses has shown conclusively that damage can occur during any stage of the soldering operation. Mechanical damage can occur during lead bending and clipping. High-impedance devices such as MOSFETs and high-frequency transformers have been accidentally damaged by the accumulated static charge on clothing, human bodies and other insulated objects. Acid-activated soldering fluxes have promoted stress corrosion of component leads. The majority of failures, however, have been due to inadequate temperature controls during:

(i) Degolding and pretinning of component leads;
(ii) Soldering with hand-held irons;
(iii) The reworking of soldered joints.

Quality audits performed at contractors' soldering stations have revealed that operators were occasionally deviating from the process instructions that have been prescribd by ESA (ESRO) for the past ten years[1]. The soldering parameters covered by these instructions include permitted solder-bath temperature, soldering-iron temperatures, dwell times and the need for heat sinks to be applied to certain component leads. In view of the continuing occurrence of heat-damaged components, it was considered expedient to perform a short programme of work, the aim of which was to reassess the suitability of the prescribed ESA soldering parameters. The work was to consist in simulating various soldering operations and measuring the temperatures attained by lead materials immediately adjacent to their component bodies. The efficiency of various soldering aids and of applying specially constructed pretinning tools and commercially available heat sinks was also to be assessed. It was felt that this work would supplement previous work in which the effect of temperature and thermal shock on the reliability of printed circuit board plated-through holes was evaluated. (These holes can become degraded when plated tin/lead circuitry is fused[2], during solder floating and during hand soldering[3].)

One aim of the study reported on here was to obtain data related to the temperature rises experienced by different components during soldering and to compare these values with the maximum temperature ratings contained in current component specifications.

COMPONENTS UNDER EVALUATION

Details of the various components included in this work are listed in Table 1. Also shown are the maximum soldering-temperature ratings presently agreed on by specification authorities and component manufacturers; these are considered to minimise component damage and parameter drifts.

An ESA computer-aided literature search has shown that very little has been published on the transfer of heat and damage to electronic components during pretinning, hand soldering and the repairing and 'touching-up' of soldered joints. Two detailed papers[4,5] concern theoretical models, mainly relevant to the process of wave soldering. Here, parameters of temperature and time may be defined in such a way as to control the heating of component lead materials sufficiently for them to become wetted by the molten solder. The heat capacity, C, of a certain material (e.g., a solder, lead material or component package) is equal to the product of its volume, V, its density, ϱ, and its specific heat capacity, c. Table 2 is taken from the paper by Klein Wassink[5]. As can be seen, the coefficient of thermal conductivity, λ, differs considerably among the various materials listed. On the other hand, the heat capacities

Table 1
Details of Components Under Study

Component Type	Specification	Component	Maximum Permitted Soldering Conditions (according to specification) Temperature	Time	Distance
Resistor RNC 50 Axial leads	SCC 4001/009	Cu (99·9%)	245°C	10 s	1·6 mm
Resistor RNC 90 Radial leads	MIL–R–55182/9	Cu	350°C	3 s	0·125 in.
Capacitor CKR 05 Radial leads	SCC 3001/008	Cu	260°C	10 s	3 mm
Capacitor CKR 06 Radial leads	SCC 3001/006	Cu	260°C	10 s	3 mm
Diode IN 4148 Axial leads	SCC 510/001	Ni/Fe/Mn 42:57:1	260°C	10 s	1·5 mm
Diode IN 5811 Axial leads	SCC 5101/013	Cu	260°C	10 s	1·5 mm
Transistor 2N 2905	SCC 5205/002	Fe/Ni/Co (53:29:17) (Kovar)	260°C	10 s	1·5 mm

Table 2
Product of the Density ϱ and the Specific Heat Capacity c, with the Thermal-Conductivity Coefficient λ of some Metals, Alloys and Materials Utilised in the Assembly of Printed-Circuit Boards

Material	ϱc (J/cm³ °C)	λ (W/m °C)
Iron	3·7	75
Copper	3·5	370
Aluminium	2·4	230
Fe-Ne-Co alloy	3·7	16
Brass	3·3	100
Plastics	about 2	about 0·2
Glass	2	1
Solder (eutectic tin-lead)	1·7	50

From Reference 5.

of given volumes of these materials are very similar. It is worth noting that the materials of the component leads chosen for this study (copper and Ni/Fe/Co alloys, see Table 1) possess very different coefficients of thermal conductivity.

Mass component-assembly processes that have set soldering parameters (time and temperatures of preheating, contact with liquid solder, amount of flux, etc.) can be closely controlled and lend themselves to modelling, so thermal damage to components can be avoided by close parameter controls[5]. Although wave soldering is permitted by ESA, it is seldom applied, since the small number of identically designed spacecraft circuits does not warrant the setting-up of unique machine parameters for each individual board lay-out[6].

The components selected for the present evaluation are those that are regularly chosen by ESA contractors and hand-soldered by trained and qualified operators. The process of hand soldering involves a large number of variables. These include:

(i) The manual dexterity of the operator;
(ii) The choice of soldering iron and the thermal capacity of its tip;
(iii) The solderability of the surfaces to be joined;
(iv) The volume and latent heat of vaporisation of the flux;
(v) The lay-out of the printed circuit board;
(vi) The side to which solder is applied.

In view of this multiplicity of variables, it is considered impossible to assess the temperatures attained by components on the basis of simple modelling techniques. Instead, the temperatures reached by each component type must be evaluated separately by using actual temperature-measuring techniques.

EXPERIMENTAL PROCEDURES

Temperature-Measuring Technique

Miniature thermocouples were made by welding together Nichrome and nickel leads (type K) 0·1 mm in diameter. They were found to have a negligible thermal-sink effect, a rapid temperature response and a reasonable accuracy; only small deviations were noted between individual made-up thermocouples. The almost linear EMF/temperature relationship for such thermocouples enabled millivolts to be recorded directly without the need for compensation. Spot soldering ensured a good contact between each welded thermocouple lead and component lead. The contact was located on the lead adjacent to its glass-to-metal seal or component body by means of an activated flux and a small amount of high melting point solder alloy (1% Pb, 1·5% Ag, rest Sn; melting point—315°C). As an additional means of ensuring good mechanical strength, the thermocouple leads were glued to the various component bodies with an RTV silicone adhesive (see Figure 2). The essential features of the temperature-measuring arrangement are shown in Figure 3.

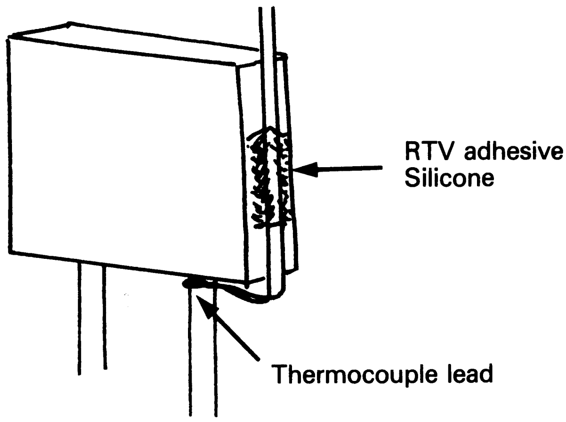


Fig. 2 *Thermocouples were glued to each component body to ensure good mechanical strength. The thermocouple weld beads were spot soldered to the lead immediately adjacent to the component body.*

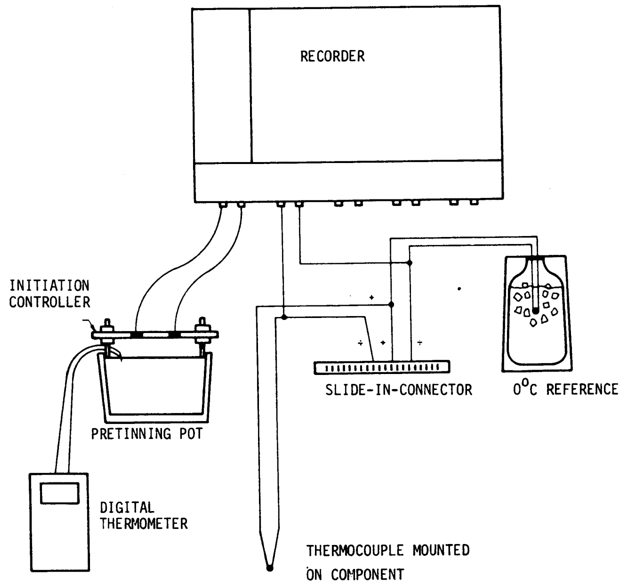


Fig. 3 *Schematic drawing of experimental set-up.*

An FP 2100 digital thermometer, type 2120, monitored the ambient, solder-lead and solder-tip temperatures. Measurements of time and temperature during each soldering operation were recorded on a Watanabe linear recorder, type WTR 331-8C, calibrated at 1·6 mV/cm and running at a speed of 10 mm/s. The combined accuracy of the recorder and pen (1·5%) and thermocouple (2%) is estimated to provide for a measured temperature tolerance of approximately 8°C.

Soldering Operations

All soldering operations were performed by one person, who had followed an ESA-approved soldering course and had spent several years as a qualified operator assembling spacecraft electronics. A very pure eutectic tin/lead soldering alloy was used, in combination with a very mildly activated, rosin-based flux.

Pretinning

Specially constructed equipment made it possible to perform all pretinning operations under closely controlled conditions. The pretinning arrangement is depicted in Figure 4, which shows how each component lead could be immersed in the liquid solder to a distance of 2 mm from the component body. The pretinning tool was designed to accommodate various heat-sinking devices, which could also be applied for degolding operations. Figure 5 shows how these devices can hold either radial and axial components or transistors; the captions identify the heat-sink material and indicate whether it is placed in contact with the component body or the component lead. During the experiments, each component was pretinned for a period of 10 seconds, in order to register the long-time effect of the heat sinks. The set-up is that illustrated in Figure 3. Each component was finally inspected for satisfactory solder coverage. The experiment was then repeated, but different immersion depths were used. Oxide dross was removed from the surface of the solder bath before each pretinning operation.

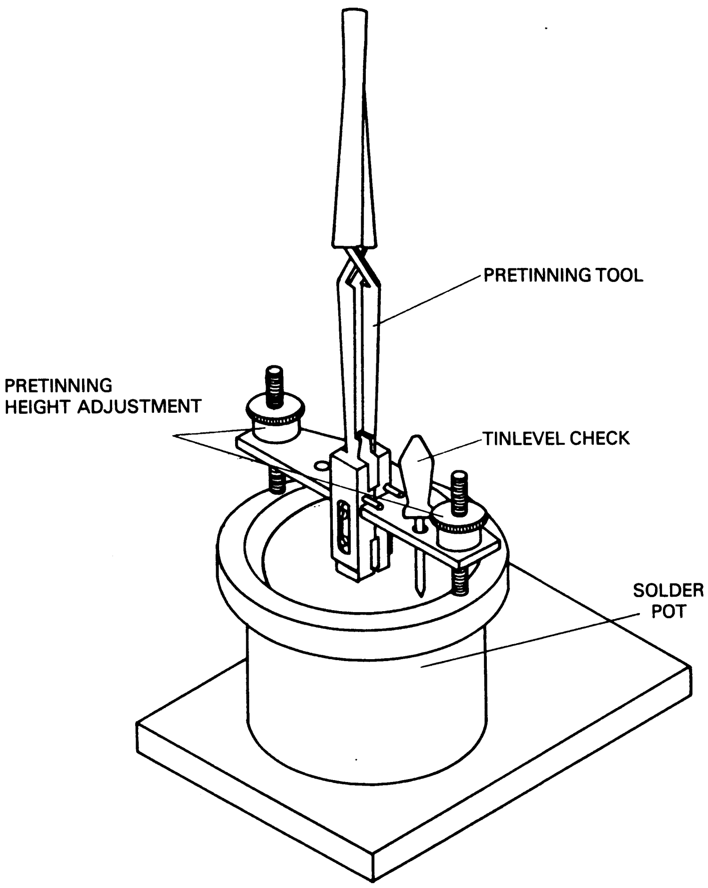


Fig. 4 *Pretinning arrangement, featuring the special pretinning tool.*

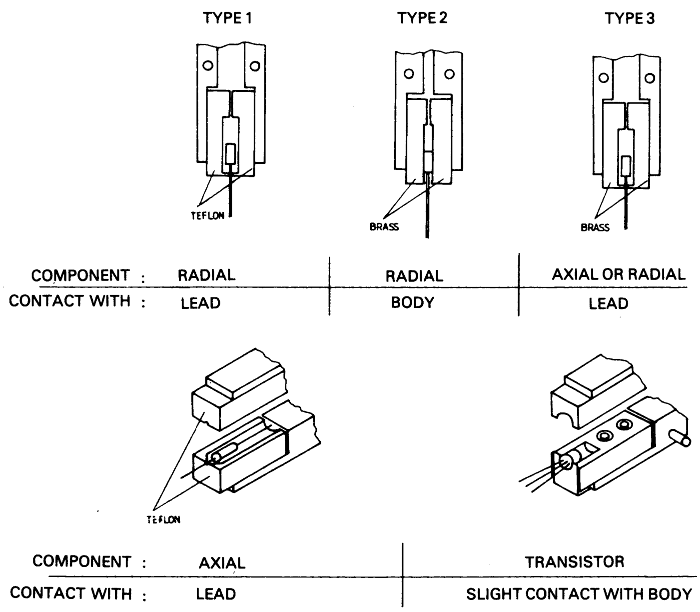


Fig. 5 *Configuration of the types of heat sinks that locate into the pretinning tool.*

Soldering

The measuring set-up for soldering was the same as that used for the pretinning operation, but no initiation controller was employed. The components were mounted onto double-sided printed circuit boards having plated-through holes and standard solder-pad areas on both sides. No conductor tracks joined these solder pads, therefore the boards were assumed to possess minimal heat-sink effects. The component-lead/hole ratios complied with the ESA specification[1], and the board finish was fused tin/lead. The radial components were so mounted as to provide a stand-off distance of 3 mm. The axial components were mounted with a stand-off of 0·5 mm and with 4 mm between holes. All leads had stress-relief bends and their joints were stud mounted; none of the leads was clinched.

The soldering operations were performed with four types of soldering-iron tips (all iron-plated copper):

Type (screwdriver shape)	Average working temperature
S6 small no. 6(PT-H6)	310°C
L6 large no. 6(PT-B6)	310°C
S8 small no. 8(PT-A8)	400°C
L8 small no. 8(PT-C8)	400°C

It is recognised that the correct model of iron should be chosen for each specific job and that this will depend on the thermal capacity of the parts to be joined. The chosen temperature of 320°C represents the maximum rating recommended by ESA[1]. The temperature of 400°C represents a typical uncontrolled tip that might damage both a component and the circuit to which the latter is being joined.

Either the soldering operations were performed from the usual soldering side of the printed circuit board, or the solder wire and iron were applied to the lead at the component side of the circuit. The second method is frequently employed during the assembly of components on thick (possibly multilayer) boards that possess large ground plane areas. In this case, the close proximity of the iron tip may be expected to bring about a more rapid rise in component body temperature.

Soldering with Heat Sinks

Heat sinks of many kinds have been applied to component leads during hand soldering operations (see Figure 6). The most suitable device, type A, was the one employed during the component-temperature monitoring experiments.

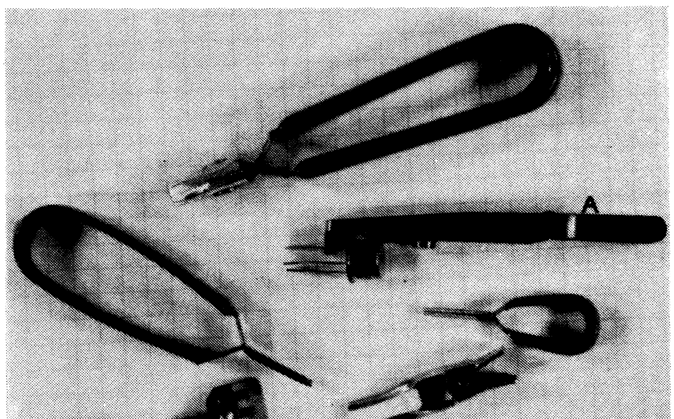


Fig. 6 *Various forms of heat sinks that clamp onto leads between the component body and the soldering point to prevent overheating. Type 'A' was of some use.*

Desoldering

Occasionally, soldered joints on spacecraft printed circuit boards will have to be repaired, either because they cannot be properly reworked (i.e., 'touched up') or because a component has to be removed. This operation was performed after each of the assembly stages described in the previous two sections. Again heat sinks were occasionally applied to certain component leads, and all component-lead temperatures were recorded as a function of the time required to effect complete removal of solder and lead from their plated-through holes.

Various procedures for the repair of soldered joints and circuits have been recommended by ESA[7]. As a rule, operators have tended to use *fluxed copper braid* which, when it has been laid on the solder to be removed, is then pressed with the hot iron. As the solder melts, it is drawn up from the joint and into the braid by capillary attraction. An alternative method that is also permitted is the use of desoldering machines which incorporate heating and *vacuum solder-sucking facilities*. Both methods were employed during the experiments.

Summary of Soldering Operation Variables

Pretinning Variables

(i) Component types;
(ii) Lead materials;
(iii) Solder-bath temperatures;
(iv) Pretinning times;
(v) Depth of component-lead immersion into solder bath;
(vi) Application of various heat sinks located within pretinning tool.

Soldering Variables

(i) Component types;
(ii) Lead materials;
(iii) Soldering-iron tip size and temperature;
(iv) Presence or absence of heat sinks during soldering;
(v) Application of heat from soldering side or from the component side of the printed circuit board;
(vi) Various transistor off-set heights.

Desoldering Variables

(i) Component types;
(ii) Lead materials;
(iii) Soldering-iron tip size and temperature;
(iv) Presence or absence of heat sinks;
(v) Application of heat from the soldering side or from the component side of the printed circuit board;
(vi) Use of wicking braid or commercial vacuum solder-sucking equipment;
(vii) Various transistor off-set heights.

RESULTS AND DISCUSSION

Pretinning Results

Sixty-eight curves have been plotted, showing the rise in temperature measured by thermocouples attached to the many component-lead/body interfaces. An example is shown in Figure 7, but the mass of recorded data points has been compiled into Tables 3 to 7. The format of these tables enables the efficiency of the various heat sinks to be evaluated. The data relate to the radially and axially leaded components; heat sinking was not applied to the transistor samples.

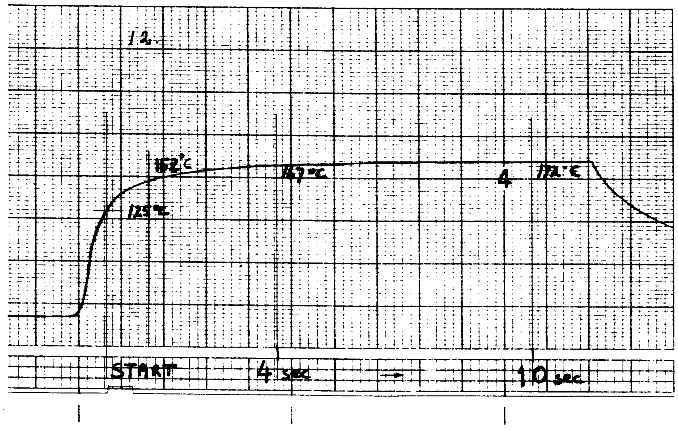
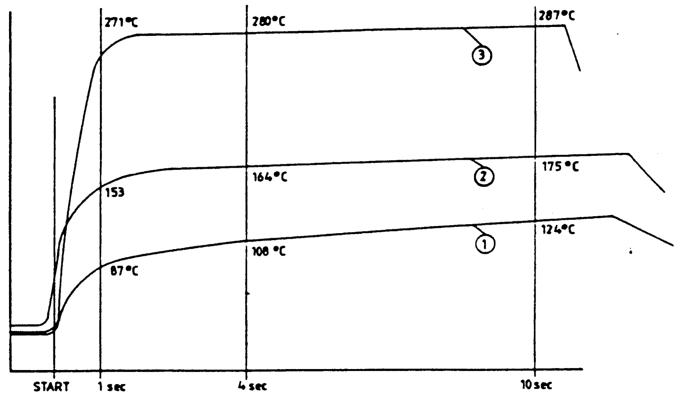


Fig. 7 *Typical temperature/time curve showing the component's rise in temperature during pretinning.*

Present ESA soldering requirements state that all component leads shall be pretinned for two to three seconds at a bath temperature of 220±10°C. As can be seen, this bath temperature is below the maximum temperature ratings of components listed in Table 1, so thermal damage should not normally be expected. A comparison of Tables 3 and 5 with Table 1 gives confidence that damage will not be inflicted if this prescribed bath temperature is not exceeded. If the bath should become too hot, however, and possibly reach 300°C, then several of these components (particularly the RNC 50 resistor and the deeply immersed capacitors) will become permanently damaged unless protected by heat sinks. It must be noted that the ESA degolding requirements[1] for gold-plated leads permit dipping to be performed at up to 280°C for two to three seconds. In the case of the diode IN 4148, therefore, it is recommended that protective heat sinks should always be applied.

Figure 8 shows the temperature curves for the transistor, the leads of which were not protected by proper heat sinking (see Figure 5, type 5). With a maximum temperature rating of 260°C for ten seconds at a distance of 1·5 mm from the component body, it can be seen that degolding transistors at the maximum permitted solder-bath temperature could cause marginal damage. The curves incorporated in Figure 8 make clear the importance of maintaining adequate clearance between the transistor body and the surface of the solder bath. When the pretinning process is observed under a binocular microscope, it will be noticed that some half seconds are needed for the liquid solder to wet the gold-plated lead. As the component lead heats up, the solder meniscus rises up the lead with a corresponding lowering of the wetting angle. The excellent solderability of these component leads produces a large positive meniscus, which further reduces the distance between component body and liquid solder. The process of heating the component body is also accelerated by the thermal conduction/radiation to which the latter is subjected in close proximity to the molten solder surface. Gold must be thoroughly removed from such leads, in order to avoid the embrittlement of subsequent soldered joints. It is not possible to maintain sufficient control of the lead-immersion depth when degolding by hand, however, and pretinning tools similar to the one shown in Figure 4 should always be employed.



PRETINNING CONDITIONS FOR TRANSISTOR :

CURVE 1 : SOLDER POT TEMPERATURE 220°C
DISTANCE TO BODY 2 mm

CURVE 2 : SOLDER POT TEMPERATURE 300°C
DISTANCE TO BODY 2 mm

CURVE 3 : SOLDER POT TEMPERATURE 300°C
DISTANCE TO BODY 1 mm

Fig. 8 *Superimposed temperature/time curves for transistor 2N 2905 during pretinning, to highlight effects of different bath temperatures and immersion depths.*

The results of pretinning type CKR 06 capacitors (which have copper leads) to different immersion depths, either with or without heat sinks, are shown in Table 7. This information is complementary to that presented in Table 2. It is interesting to compare the copper-lead data with those from Fe/Ni/Co-alloy leads (e.g., curve 1 in Figure 8). Under similar conditions of temperature and immersion depth, component bodies attached to copper leads will quickly rise to a markedly higher temperature than those possessing Fe/Ni/Co-alloy leads.

Each component lead was visually inspected after the various pretinning processes. All results showed good solder coverage, except in the case of some leads that had been protected by the special brass heat sink (Figure 5, type 3), which was clipped in direct contact with either copper or alloy leads. The efficiency of the brass heat sink is so good that molten solder surrounding these leads is prematurely solidified. This effect occasionally caused a thick build-up of solder towards the solder meniscus, as shown in Figure 9. Such build-ups prevent these leads from being inserted into plated-through holes that have diameters specially designed for each component type. The Teflon heat sinks were considered to be the most practical for pretinning, and it was observed that they also guarded the components against flux and solder splashing during immersion into the bath.

Heat sinking provided through the component bodies (type 2) was less effective than the other types, but is considered suitable for the lower pretinning temperatures.

Soldering Results

The temperatures attained during the assembly of capacitors, resistors, diodes and transistors on printed circuit boards are listed in Tables 8 to 11, respectively. The information contained in these tables has been

Table 3

Effect of Heat Sinks on the Measured Temperatures of Radial Components Pretinned in Solder at 220°C

Type of Heat-Sink (See Figure 5)	*Temperature Measured °C*								
	1 Second			*4 Seconds*			*10 Seconds*		
	CKR 05	*CKR 06*	*RNC 90*	*CKR 05*	*CKR 06*	*RNC 90*	*CKR 05*	*CKR 06*	*RNC 90*
1. Teflon, on leads	137	155	139	168	171	161	182	187	174
2. Brass, on body	152	157	157	167	171	170	172	177	176
3. Brass, on leads	90	103	109	131	113	117	144	117	125
No heat-sink	157	153	159	188	177	177	205	192	191

Table 4

Effect of Heat Sinks on the Measured Temperatures of Radial Components Pretinned in Solder at 300°C

Type of Heat-Sink (See Figure 5)	*Temperature Measured °C*								
	1 Second			*4 Seconds*			*10 Seconds*		
	CKR 05	*CKR 06*	*RNC 90*	*CKR 05*	*CKR 06*	*RNC 90*	*CKR 05*	*CKR 06*	*RNC 90*
1. Teflon, on leads	195	199	191	237	223	215	268	246	242
2. Brass, on body	225	217	220	230	232	234	238	238	239
3. Brass, on leads	156	149	133	168	158	140	170	168	148
No heat-sink	210	229	225	250	252	244	273	269	261

Table 5

Effect of Heat Sinks on the Measured Temperatures of Axial Components Pretinned in Solder at 220°C

Type of Heat-Sink (See Figure 5)	*Temperature Measured °C*								
	1 Second			*4 Seconds*			*10 Seconds*		
	RNC 50	*IN 4148*	*IN 5811*	*RNC 50*	*IN 4148*	*IN 5811*	*RNC 50*	*IN 4148*	*IN 5811*
4. Teflon, on leads	125	144	129	156	159	172	172	173	191
3. Brass, on leads	94	62	98	100	67	119	103	70	125
No heat-sink	183	147	151	197	183	189	203	193	203

Table 6

Effect of Heat Sinks on the Measured Temperatures of Axial Components Pretinned in Solder at 300°C

Type of Heat-Sink (See Figure 5)	*Temperature Measured °C*								
	1 Second			*4 Seconds*			*10 Seconds*		
	RNC 50	*IN 4148*	*IN 5811*	*RNC 50*	*IN 4148*	*IN 5811*	*RNC 50*	*IN 4148*	*IN 5811*
4. Teflon, on leads	185	135	220	223	203	250	241	227	267
3. Brass, on leads	171	76	143	180	88	164	180	90	170
No heat-sink	219	193	220	246	257	257	255	272	274

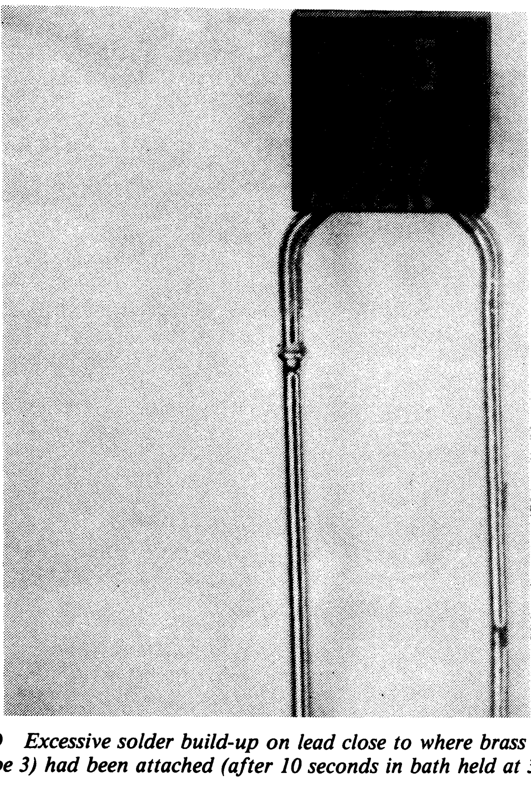


Fig. 9 *Excessive solder build-up on lead close to where brass heat sink (Type 3) had been attached (after 10 seconds in bath held at 300°C.).*

Table 7

Effect of Solder Bath*-to-Body Distance on the Measured Temperature of CKR 06 Capacitors During Pretinning

Distance to Body	*Temperature Measured*		
	1 Second	*2 Seconds*	*10 Seconds*
7 mm	43	50	59
5 mm	115	141	164
4 mm	137	158	177
3 mm	145	166	184
2 mm	154	179	195

* Solder bath temperature was 220°C.

compiled from more than 100 curves recorded during this part of the study. Several of the temperature/time curves recorded by the test equipment are presented in Figure 10. The various individual soldering parameters have been described under Soldering Operations.

The full results have been tabulated, for completeness, but they are not analysed in detail, because of the great complexity in the relationships among the various parameters. Each line of results can be usefully referred to during future component-assembly design reviews, materials review boards, component-failure analyses, etc., when such specific information may be required.

Some general observations may be made on the basis of the experimental results:

(i) Under none of the soldering conditions did heating cause the components to exceed their maximum permitted temperature rating, as listed in Table 1 (even when the soldering was performed from the component side with the highest bit temperature).

Table 8
Maximum Temperatures Measured During Soldering and Desoldering Capacitors (Type CKR 06)

		Soldering Iron		*Time*		*PCB Side*			
Measuring Number	*Heat-Sink Type*	*Temperature*	*Tipsize*	*Soldering*	*Solder Removal*	*Max. Temp. Measured*	*A*	*B*	*Remarks*
70	none	294	S6	4·3		153	×		
71	none	302	S6		12·6	182·5	×		WB
72	none	335	L6	2·5		167	×		
73	none	330	L6		5·3	183	×		WB
74	none	388	S8	1·7		172	×		
75	none	390	S8		2·8	167	×		WB
76	none	422	L8	1·5		183	×		
77	none	420	L8		4·5	213	×		WB
78	none	307	S6	(4)		173		×	
79	none	288	S6		11·2	211		×	WB
80	none	320	L6	3·2		199		×	
81	none	325	L5		5·8	212		×	WB
82	none	360	S8	4·2		236		×	
83	none	414	S8		6	225		×	WB
84	none	390	L8	3		245		×	
85	none	370	L8		3·4	261		×	WB
86	none	305	S6	5·7		160	×		
87	none	263	S6		9·5	160	×		WB
88	none	260	S6	8·2		183		×	
89	none	265	S6		9·4	195		×	WB
90	none	305	L6	2·7		168	×		
91	none	328	L6		3·7	163	×		WB
92	none	325	L6	6·5		222		×	1
93	none	325	L6		6·2	205		×	WB
94	none	430	S8	1·6		160	×		
95	none	428	S8		3·8	174	×		WB
96	none	413	S8	4·5		231		×	
97	none	422	S8		6	218		×	WB
98	none	395	L8	3·2		217	×		
99	none	423	L8		4	213	×		WB
100	none	420	L8	4·3		228		×	1
101	none	412	L8		3·1	223		×	WB
102	steelclip	318	S6	6·8		144	×		
103	sleelclip	317	S6		10	153	×		WB[2]
104	steelclip	328	S6	10		161		×	3
105	steelclip	303	S6		7·5	132		×	WB[3]
106	steelclip	410	S8	4·1		163	×		
107	steelclip	406			5·5	162	×		WB
107A	steelclip	420	L8	4		184	×		
107B	steelclip	427	L8		3·5	175	×		WB
108	none	303			3·7	163	×		Vacuum
109	none	303			2·5	156	×		Vacuum
110	steelclip	303			2·8	113	×		Vacuum
111	steelclip	315	L6	4·7		154	×		
112	steelclip	328	L6		4·3	140	×		WB

1 = Difficult to make soldering iron contact.
2 = Unsuccessful removal of solder due to efficiency of heat sink.
3 = Inaccessible solder joint due to presence of heat sink.

A = SOLDER SIDE.
B = COMPONENT SIDE.
WB = WICKING BRAID.

Table 9
Maximum Temperatures Measured During Soldering and Desoldering Resistors (RNC 50)

		Soldering Iron		*Time*		*PCB Side*			
Measuring Number	*Heat-Sink Type*	*Temperature*	*Tipsize*	*Soldering*	*Solder Removal*	*Max. Temp. Measured*	*A*	*B*	*Remarks*
113	none	333	L6	2·8		165	×		
114	none	330	L6		3	159	×		WB
115	none	330	L6	3·6		190		×	
116	none	319	L6		5·4	214		×	WB
117	steelclip	330	L6	4·2		122	×		
118	steelclip	326	L6		3·6	111	×		WB
119	steelclip	320	L6	2·8		140		×	
120	steelclip	320	L6		6	144		×	WB

A = SOLDER SIDE.
B = COMPONENT SIDE.
WB = WICKING BRAID.

Table 10

Maximum Temperatures Measured During Soldering and Desoldering Diodes (IN4148)

		Soldering Iron		*Time*			*PCB Side*		
Measuring Number	*Heat-Sink Type*	*Temperature*	*Tipsize*	*Soldering*	*Solder Removal*	*Max. Temp. Measured*	*A*	*B*	*Remarks*
121	none	327	L6	3·6		112	×		
122	none	330	L6		4·4	125	×		WB
123	none	328	L6	3·8		187		×	
124	none	330	L6		4·5	189		×	WB
125	steelclip	332	L6	3·2		76	×		
126	steelclip	333	L6		3·2	73	×		WB
127	steelclip	333	L6	2·1		99		×	
128	steelclip	333	L6		4·9	112		×	WB

A = SOLDER SIDE.
B = COMPONENT SIDE.
WB = WICKING BRAID.

Table 11

Maximum Temperatures Measured During Soldering and Desoldering Transistors (Type 2N 2905) as a Function of Mounting Height

		Soldering Iron		*Time*			*PCB Side*		
Measuring Number	*Mounting Type*	*Temperature*	*Tipsize*	*Soldering*	*Solder Removal*	*Max. Temp. Measured*	*A*	*B*	*Remarks*
129	4 mm over PWB	329	L6	3·4		76	×		
129A	4 mm over PWB	334	L6	3·6		117		×	
130	4 mm over PWB	331	L6		3·6	82	×		WB
130A	4 mm over PWB	316	L6		5·7	114		×	WB
131	3 mm over PWB	328	L6	4·7		98	×		
131A	3 mm over PWB	327	L6	5		137		×	
132	3 mm over PWB	332	L6		4·5	98	×		WB
132A	3 mm over PWB	333	L6		6·7	144		×	WB
133	2 mm over PWB	314	L6	3·7		113	×		
134	2 mm over PWB	328	L6		4·1	113	×		WB
135	1 mm over PWB	328	L6	5·9		132	×		
136	1 mm over PWB	331	L6		6·9	>93	×		WB

A = SOLDER SIDE.
B = COMPONENT SIDE.
WB = WICKING BRAID.

(ii) The time taken to produce an acceptable soldered joint—as defined by the workmanship standards given in Reference 1—increased when heat sinks were affixed to component leads. Nevertheless, despite these times differences, the maximum temperatures reached by the components were very similar.

(iii) The same effect was observed when high-temperature soldering-iron tips were used. The soldering time became short, but the maximum measured component temperatures remained about the same as under other experimental conditions.

(iv) Practical problems were encountered, which prevented attachment of the majority of commercially available heat sinks to component leads. Generally, these heat sinks (Figure 6) are too large and heavy to be of any real use. They would be completely unsuitable for use during the assembly of high component density boards.

(v) Although heat sinks are required to protect 'delicate' components by the ESA soldering specification, it is now considered that the increased soldering times and difficulties of application militate against their use when standard soldering operations are performed. They are, however, to be recommended in special cases when high-temperature solders are applied or when a component is specified as having a maximum temperature rating of less than 245°C.

Desoldering Results

Most of the experimental desoldering operations involved the use of wicking braid, as this is the method most commonly chosen by ESA contractors. The operation implies that both the temperature and pressure applied to the joint area may be variable and fully dependent on the skills of the individual operator. Only a limited number of samples were desoldered with commercially available vacuum solder-sucking equipment, since this method was known to be less critical, lower temperatures and shorter desoldering times being employed. All the results have been recorded in the chronological order of testing, as is shown in Tables 8 to 11. Three typical temperature/time curves are included in Figure 10 (g to i).

A detailed analysis of the desoldering results has not been carried out, since they are thought to be largely operator dependent. The following general comments can, however, be made:

(i) Desoldering with wicking braid is only accomplished with long periods of applied heat (usually 4 to 5 seconds, but can be more than 10 seconds). Most components should sustain no damage, but in the absence of heat sinks the rated capacitor maximum temperature is approached.

(ii) The vacuum machine requires shorter operation times and lower temperatures than wicking braid.

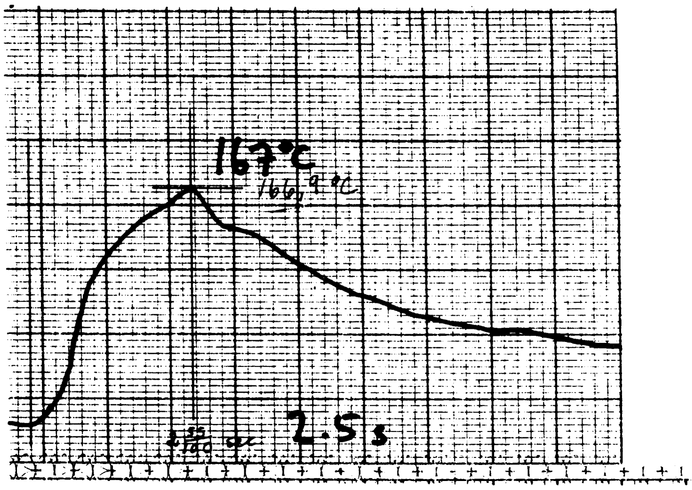
(iii) It makes little difference whether desoldering is performed from the component side or from the soldering side of a printed circuit board.

CONCLUSIONS

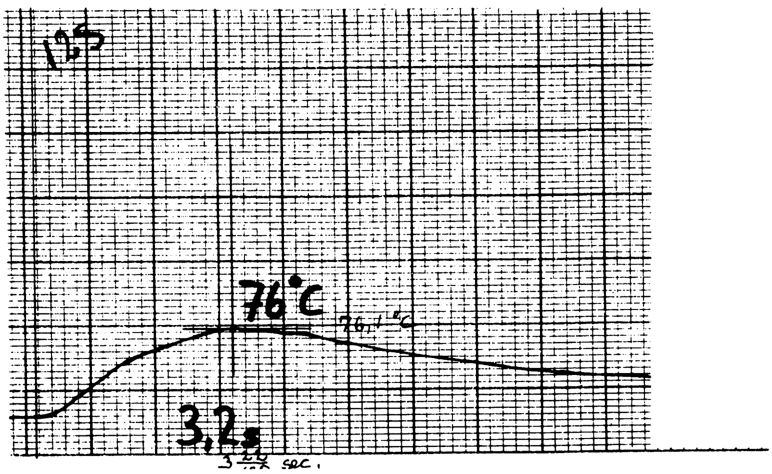
1 Temperature-measuring experiments have established the temperatures reached by various types of electronic components during manual soldering operations. Extensive data have been recorded under controlled conditions of degolding, pretinning, hand soldering and the repair of soldered joints.

2 ESA requires[1] gold platings to be removed from component leads before soldering. The *degolding* operation requires the leads to be immersed for two to three seconds in a solder bath maintained at the relatively high temperature of 280°C. Under these conditions, it is essential that protective heat sinks be attached to the leads of diodes and transistors.

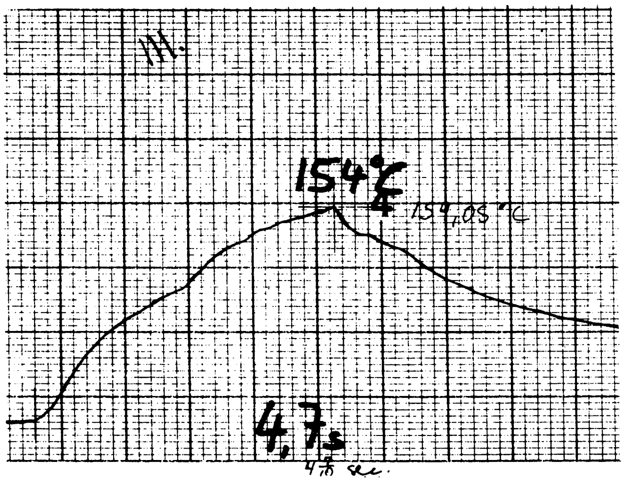
3 Special heat-sinking devices, designed to accommodate radial, axial and transistor-like components during pretinning operations, have been tested. Of the various heat-sinking materials, Teflon is considered to be the most suitable.



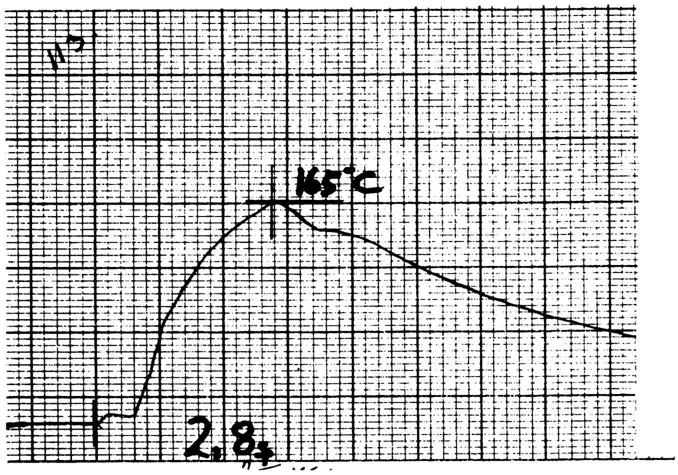
OPERATION: A. HAND SOLDERING, Cu LEAD NO HEAT SINK.
MEASUREMENT NO.: 72
COMPONENT: CKR 06
MOUNTING HEIGHT: 3 mm
TIP TEMPERATURE: 335°C
TIP SIZE: Large 6
SOLD. SIDE: Bottom side



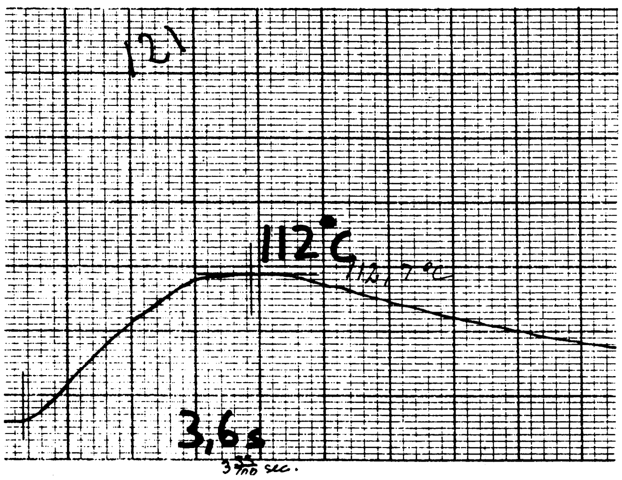
OPERATION: D. HAND SOLDERING, NiFeMn LEAD STEEL CLIP HEAT SINK.
MEASUREMENT NO.: 125
COMPONENT: IN 4148
MOUNTING HEIGHT: 0·5 mm
TIP TEMPERATURE: 332°C
TIP SIZE: Large 6
SOLD. SIDE: Bottom side



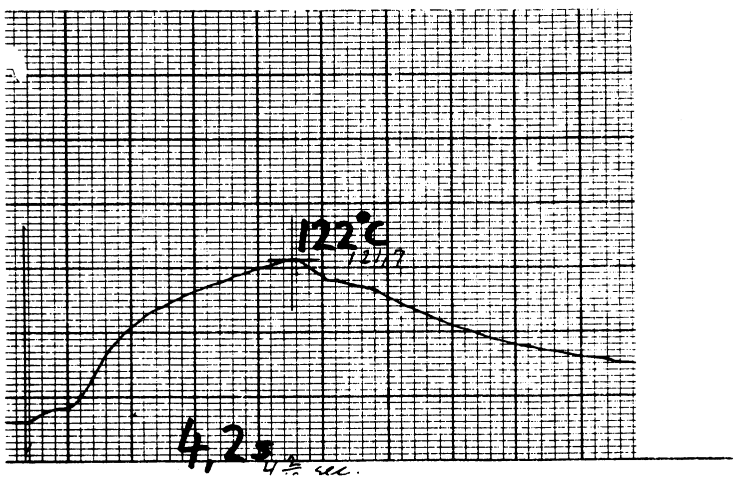
OPERATION: B. HAND SOLDERING, Cu LEAD STEEL CLIP HEAT SINK.
MEASUREMENT NO.: 111
COMPONENT: CKR 06
MOUNTING HEIGHT: 3 mm
TIP TEMPERATURE: 315°C
TIP SIZE: Large 6
SOLD. SIDE: Bottom side



OPERATION: E. HAND SOLDERING, Cu LEAD NO HEAT SINK.
MEASUREMENT NO.: 113
COMPONENT: RNC 50
MOUNTING HEIGHT: 0·5 mm
TIP TEMPERATURE: 333°C
TIP SIZE: Large 6
SOLD. SIDE: Bottom side

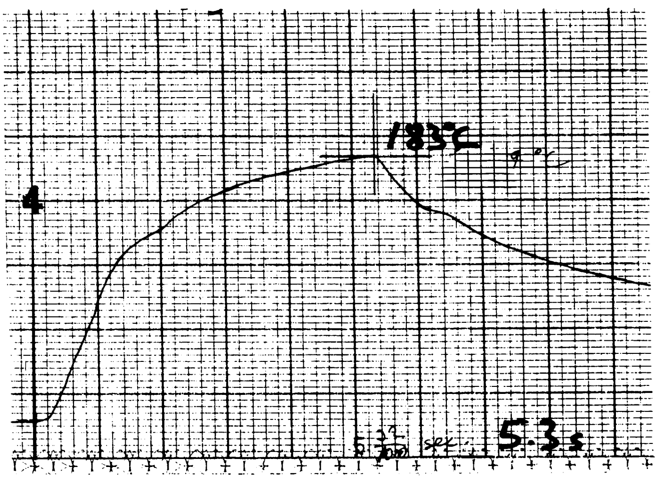


OPERATION: C. HAND SOLDERING, NiFeMn LEAD NO HEAT SINK.
MEASUREMENT NO.: 121
COMPONENT: IN 4148
MOUNTING HEIGHT: 0·5 mm
TIP TEMPERATURE: 327°C
TIP SIZE: Large 6
SOLD. SIDE: Bottom side

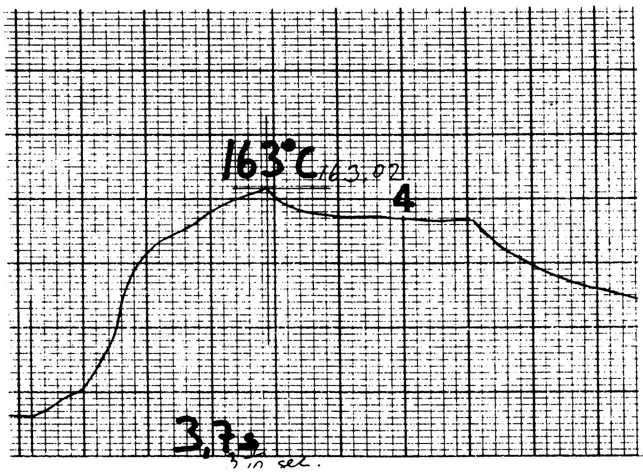


OPERATION: F. HAND SOLDERING, Cu LEAD STEEL CLIP HEAT SINK.
MEASUREMENT NO.: 117
COMPONENT: RNC 50
MOUNTING HEIGHT: 0·5 mm
TIP TEMPERATURE: 330°C
TIP SIZE: Large 6
SOLD. SIDE: Bottom side

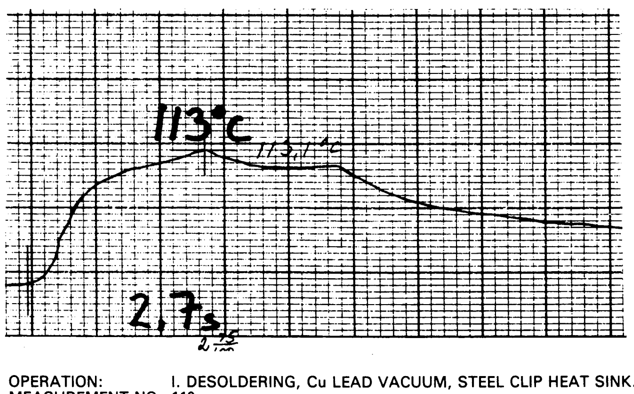
Fig. 10



OPERATION: G. DESOLDERING, Cu LEAD, BRAID, NO HEAT SINK.
MEASUREMENT NO.: 73
COMPONENT: CKR 06
MOUNTING HEIGHT: 3 mm
TIP TEMPERATURE: 330°C
TIP SIZE: Large 6
SOLD. SIDE: Bottom side



OPERATION: H. DESOLDERING, Cu LEAD VACUUM, NO HEAT SINK.
MEASUREMENT NO.: 108
COMPONENT: CKR 06
MOUNTING HEIGHT: 3 mm
TIP TEMPERATURE: 303°C
TIP SIZE: Standard Equipment
SOLD. SIDE: Bottom side



OPERATION: I. DESOLDERING, Cu LEAD VACUUM, STEEL CLIP HEAT SINK.
MEASUREMENT NO.: 110
COMPONENT: CKR 06
MOUNTING HEIGHT: 3 mm
TIP TEMPERATURE: 303°C
TIP SIZE: Standard Equipment
SOLD. SIDE: Bottom side

Fig. 10 *Charts of time versus temperature recorded during soldering and desoldering operations. More than 100 traces were made during this part of the programme, of which (A) to (I) are representative.*

4 As the prescribed[1] *pretinning* bath temperature of 220°C±10°C is below the maximum temperature rating of all components evaluated in this programme, thermal damage is not to be expected during this operation. Pretinning tools that incorporate heat-sinking devices are not essential, therefore, but they do protect components from flux and solder splatter and they can maintain a set distance between the liquid solder and the component body.

5 Component assembly on printed circuit boards by *manual soldering* with standard soldering-iron tips did not cause any of the components to reach their maximum temperature ratings. Tips held in excess of the maximum temperature of 320°C permitted by ESA were noted as unlikely to cause component damage provided that lead-forming rules are adhered to and soldering times kept short.

6 The application of heat sinks to component leads during manual soldering increased the time required to produce acceptable solder fillets. Such heat sinks are not generally necessary to prevent overheating and are not recommended for standard soldering operations.

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