Evaluating Soldering Irons for Lead Free Assembly - A Quantitative Approach

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Abstract

Transition to lead free solder stations in electronics packaging has raised issues regarding process, metallurgy and reliability m assemblies. In regards to soldering, lead has been used for thousands of years in a wide range of applications. Conventional eutectic or near eutectic tin-lead solder compositions have been used for virtually all soldering applications in electronics assembly for the last 50 years, In the electronics assembly process, a majority of commercial rework applications and some low density board assembly processes require hand soldering stations. Managers and operators, alike, are faced with a decision to make a selection from a suite of commercially available choices wherein cost by itself cannot be the only deciding factor, Tin-lead soldering Stations have much lower operating temperatures and, with longer tip lives as compared to those of lead free soldering stations, soldering temperature becomes a significant factor which can impact the quality of soldering using lead free soldering stations. Apart from differences like the ones mentioned earlier, an evaluation of soldering stations should also include ergonomic and operational characteristics. To make matters more difficult, there is not a lot of help in the form of published guidelines that can aid in making this selection. This paper describes an attempt to quantify both qualitative and quantitative data that can aid in the evaluation of lead free soldering irons.

Introduction

Primarily due to overseas legislative actions, many sectors of the electronics industry need to be lead free starting July , 2006. This is not just a result of the business strategies or environmental concerns but also a result of market pressures, driven by mandates from Japan and the EU. As a result of this, soldering equipment needs to be upgraded to lead-free from tin-lead. In the electronics assembly process, a majority of commercial rework applications and some low density board assembly processes still require hand soldering stations. Furthermore, many small scale manufacturers assemble low density boards using hand soldering stations.

For decades, operators have been using soldering irons with operating temperatures of little over 183℃ (the melting point of tin-lead solder). Now with the transition to lead-free, the melting point of the solder has increased and the old soldering stations cannot be used for lead free soldering. Due to higher operating temperatures (~217℃) with lead-free solders, the process window for hand soldering has been reduced. It has become increasingly difficult to get good solder joints without burning the boards, components, etc. Selection of a good soldering station that meets the requirements of a lead free process, that is comfortable to operators, and that does not burn the boards or components is a major step towards the transition to lead-free.

Managers and operators, alike, are faced with this decision to make a selection of a suitable soldering station from a suite of commercially available choices wherein cost by itself cannot be the only deciding factor. There are other aspects, like technical attributes, operational performance, and ergonomics of the operator, among others, on the basis of which the soldering station should be selected. In this study, an attempt to quantify both qualitative and quantitative data that can help managers in evaluation of lead free soldering stations is undertaken.

Experimental Setup

The test vehicle used was an IPC standard test board for lead free applications. In this experiment, we have compared the company's current soldering iron (Soldering Iron I Metcal) to a competing soldering iron (Soldering Iron II Solderite). The soldering wire used was a silver-copper (SAC) alloy with a composition of 96.5Sn3AgO.5Cu by weight percent and the flux type used was water soluble. Three operators were chosen to be part of this experiment, each one of the operators was provided with a soldering station to conduct the experiment. There were an equal number of different types of surface mount and through-hole components. The operators were already accustomed to one of the soldering irons (Soldering Iron I Metcal) and, since this is a comparative study, the competing/newer soldering iron (Soldering Iron II Solderite) was compared against the legacy soldering iron A practice board was also provided to the operators to get accustomed to Soldering Iron II before the actual experiment.

When making decisions, several, criteria are often considered. These criteria include attributes, which can be measured in economic terms like costs and profits (quantitative), as well as qualitative attributes, such as safety and ergonomics, which cannot be directly measured with economic values. Therefore, the goal in a multi-attribute decision-making experiment should be to identify both objectives and the criteria used in concluding the objective, One of the key elements Is the choice of the attributes involved, judgment is required to determine the correct number of attributes for the evaluation. The selection of these attributes is a result of interviews with the operators and managers. The evaluation was conducted in two phases, a performance attributes based evaluation (PBE) phase and a technical attributes based evaluation

(TBE) phase. During the PBE phase, a questionnaire was provided to the operators and their responses were recorded regarding their experience with Soldering Iron II. In the TBE phase, technical specifications were collected from the equipment vendors. The following section summarizes the findings of the comparison,

Results & Discussion

As aforementioned, the evaluation was performed in two phases, the motivation being to accommodate both a management and an operator point of view in making the selection. During the PBE phase of evaluation, a questionnaire was developed to include three important categories of equipment evaluation study, a) Ergonomics, b) Operational, and o) Maintenance, The questionnaire was designed keeping the three categories in mind and a total of 13 questions regarding the attributes were developed (this is coincidental to the number of attributes in the technical comparison - the TBE and PBE attributes were independent of each other). The attributes were classified into the above mentioned categories as this study is an effort to quantify both qualitative and quantitative characteristics of soldering station evaluation. Assigning weights to attributes was helpful in giving priority to important attributes in a weighted-scoring approach. A questionnaire was used to quantify attributes and also to facilitate analysis; it was developed based on interviews with operators and managers.

Each of the three operators assigned points to questions, keeping performance of Soldering Iron I (Metcal the legacy iron) as a basis for comparison. The points assigned were on a scale of 1-5, For example, a score of 4 or 5 was given to Soldering Iron II (Solderite) if it performs better as compared to Soldering Iron I (Metcal) on a particular attribute, the operators assigned a score of 3 if it were to be equal in performance to Soldering Iron I for an attribute, or a lower score (1 or 2) if Soldering Iron I was preferred for that attribute. Based on the weights assigned to the individual attributes, a weighted score was obtained. Each of the attributes was assigned a particular weight (0-1) based on the importance of the attribute to the soldering iron evaluation. A higher priority attribute would have higher weights (closer to 1) and lower priority attributes would have weights (closer to 0) as shown in Table I. Also in Table I, the attributes (Ergonomics, Operational, and Maintenance) are listed.

Table I Wieghted Scores Of Lead Free Phase for Soldering Iron I (Metcal)

Questions	Weight	Operator # 1 Score 1-5	Weighted	Operator # 2 Score 1-5	Weighted	Operator # 3 Score 1-5	Weighted
Ergonomics							
Is it easier to work with this soldering station?	0.5	3	1.5	3	1.5	3	1.5
Is it easier to Clean/Replace the Tip?	0.5	3	1.5	3	1.5	3	1.5
What features don't you like?	0.4	3	1.2	3	1.2	3	1.2
What features do you like?	0.4	3	1.2	3	1.2	3	1.2
Operational							
Does this station heat up faster? Do you like that?	0.6	3	1.8	3	1.8	3	1.8
Does this station perform better soldering fine pitch?	0.8	3	2.4	3	2.4	3	2.4
Does this station solder faster than the other?	0.7	3	2.1	3	2.1	3	2.1
Does this station cool faster? Do you like that?	0.5	3	1.5	3	1.5	3	1.5
Does this station take longer to change tips?	0.5	3	1.5	3	1.5	3	1.5
Issues with this unit burning boards, components, etc?	0.7	3	2.1	3	2.1	3	2.1
Is it easier to control temperature with this station?	0.8	3	2.4	3	2.4	3	2.4
Maintenance							
Is it easy to maintain a good working soldering tip?	0.7	3	2.1	3	2.1	3	2.1
TOTAL SCORE			21.3		21.3		21.3

As this is a comparative evaluation study against a legacy tool for Soldering Iron I, all of the operators assigned a score of 3 to all attributes in scoring Soldering Iron 1 The comparative evaluation approach was employed in this study as operators were quite accustomed to using Soldering Iron I in the past and there was no necessity to conduct an experiment using Soldering Iron L Another important reason being it would have been difficult for the operators to assign points to Soldering Iron n without any comparison.

Hence, Table I was generated based on weights and common score of 21.3 was computed for all three operators.

Table I, the attributes (Ergonomics, Operational, and Maintenance) are listed.

Table II Wieghted Scores Of Lead Free Phase for Soldering Iron II (Solderite)

Questions	Weights	Operator # 1 Score 1-5	Weighted	Operator # 2 Score 1-5	Weighted	Operator # 3 Score 1-5	Weighted
Ergonomics							
Is it easier to work with this soldering station?	0.5	4	1.5	3	1.5	3	1.5
Is it easier to Clean/Replace the Tip?	0.5	3	1.5	3	1.5	3	1.5
What features don't you like?	0.4	4	1.2	3	1.2	4	1.2
What features do you like?	0.4	5	1.2	5	1.2	5	1.2
Operational							
Does this station heat up faster? Do you like that?	0.6	4	1.8	3	1.8	3	1.8
Does this station perform better soldering fine pitch?	0.8	3	2.4	3	2.4	3	2.4
Does this station solder faster than the other?	0.7	4	2.1	3	2.1	3	2.1
Does this station cool faster? Do you like that?	0.5	3	1.5	3	1.5	2	1.5
Does this station take longer to change tips?	0.5	1	1.5	1	1.5	5	1.5
Issues with this unit burning boards, components, etc?	0.7	5	2.1	3	2.1	3	2.1
Is it easier to control temperature with this station?	0.8	5	2.4	5	2.4	3	2.4
Maintenance							
Is it easy to maintain a good working soldering tip?	0.7	4	2.1	3	2.1	3	2.1
TOTAL SCORE			27		22.7		23

As expected, each of the operators provided a different score in evaluating Soldering Iron II. The weighted values were generated for each of the attributes and the total scores for each of the three operators are as tabulated. Evaluation of any equipment or process is influenced by experience. In this experiment, each of the three operators varied in their level pf expertise in hand soldering. Weights were assigned based on their experience; the operator with the most experience (Operator I) was assigned a weight of 0.8, followed by lesser experienced operator (Operator, II) being assigned a weight of 0.5, and the least experienced operator (Operator III) was assigned 0.3. After using the weights for the operators' experience, a net score for PBE was generated as follows:

Soldering Iron I: 21.3 (0.8+0.5+0.3) = 34.08 (Metcal)

Soldering Iron II: 27 + .08 + 22.7 + 0.5 + 23 + 0.3 = 39.85 (Solderite)

A similar weighting methodology was used in making comparisons using technical specifications during the TBE phase of evaluation as shown in Tables III & IV. In this phase, a matrix that lists 13 different technical attributes of the soldering irons was generated. The values for each of the technical attributes were provided by the vendors as shown in Table III

TECHNICAL ATTRIBUTES	Solder Iron II	Solder Iron I
Average cost of soldering rip ($)	10	20
Unit cost ($)	245	310
Temperature control Methodology	Tip	Tip
Temperature stability (+/- °F)	2	2
Auto sleep mode	Yes	No
Temperature Display	No	No
Tip life Warranty	1 week PB Free	1 week PB Free
Method of changing tip	Screw	Pull nut/Pull in
Time to 660°F claim by the Mfg.	6D seconds	150 seconds
Warranty	1 Year	1 Year
Quality of soldering	Very Good	Good
Spare* Availability	Good	Good
Calibration	Required	Not required

Again, each of the technical attributes was assigned a weight from 0-1 on the basis of importance. For example, attributes like warranty, cost of the equipment, were weighted 0.8 while lesser important attributes like temperature display were weighted as 0.4. The weights again were assigned based on interviews with management and operators. As mentioned earlier, Soldering Iron I was allocated a constant score of 3 for all the attributes (as the legacy tool) and the scores for Soldering Iron II (Solderite) were assigned based on comparison with Soldering Iron I. (Metcal)

Table IV: Table of weighted scores of attributes used in TBE

TECHNICAL ATTRIBUTES	WEIGHT	Soldering Iron II (Solderite)		Soldering Iron I (Metcal)	
	(0-1)	SCORE (1-5)	WEIGHTED SCORE	SCORE (1-5)	WEIGHTED SCORE
Average Cost of Soldering Tip ($)	0.8	5	4	3	2.4
Unit cost ($)	0.7	5	3.5	3	2.1
Temperature Control Methodology	0.7	3	2,1	3	2.1
Temperature Stability (+/-F)	0.8	3	2.4	3	2.4
Auto sleep mode	0,6	4	2.4	3	1.8
Temperature Display	0.4	3	1.2	3	1.2
Tip Life Warranty	1	3	3	1	3
Method of Changing Tip	0.8	2	1.5	3	2.4
Time to 660 F claim by Mfg.	0.6	5	3	3	1.8
Warranty	0,8	3	2,4	3	2.4
Quality of Soldering	0.8	4	3.2	3	2.4
Spares Availibility	0,7	3	2.1	3	2.1
Calibration	1	*2*	2	3	3
TOTAL SCORE			**32.9**		**29.1**

Table V summarizes the PBE and TBE final weighted scores for each iron and indicates that Soldering Iron II has outscored Soldering Iron I in both evaluation methodologies, making it the clear winner.

Evaluation Method	Soldering Iron I (Metcal)	Soldering Iron II
Technical Attribute Based Evaluation CTEE)	29.1	**32.9**
Performance Attribute Based Evaluation (PBE)	**34.08**	**39.85**

Conclusions

As a result of this evaluation effort, the company has elected to ma Soldering Iran II (Solderite) for its hand-soldering operations and, thus far, they are very satisfied with the results.

This effort was an effort to quantify qualitative attributes of soldering irons which would aid managers and operators in making decisions based on scientific principles and multiple attributes rather than solely on pricing, In this research, a systematic scientific method to evaluate soldering irons has been suggested. By assigning points to attributes, qualitative attributes could be quantified and having a questionnaire format would aid in collecting data of qualitative attribute.

This type of approach can be easily extended to consider more than two types of soldering stations in the evaluation process. Furthermore, the questionnaire can also be easily modified to include fewer, or more attributes - weather qualitative or quantitative.

Assigning weights to attributes based on priorities could help the decision-maker to consider (place more weight on) important Actors than on nuisance factors which are of lesser importance. As an extension to this study, a design-of experiments (DOE) approach could be developed in identifying significant factors that influence the decision, thereby non significant factors could be eliminated. For another approach, that may be of interest to academics, would be to utilize the Analytic Hierarchy Process (AHP) (see Ref [2] for more information) to determine if the final decision using that approach, is similar to the approach taken, herein.

In this paper, an unmentioned assumption is that the TBE and PBE final weighted scores for the irons were equally considered. Thus, since Soldering Iron II (Solderite) outscored Soldering Iron I (Metcal) in each of those phases, then it was the clear winner. A different situation may possibly have arisen if a soldering iron did not dominate in both the TBE and PBE final weighted scores. *In* that situation, each of the TBE and PBE Scores could be assigned weights (according to the decision maker(s). Then, to determine the winner, each soldering iron could have its overall weighted (in terms of TBE and

PBE) scores determined, For example, assuming TBE and PBE have equal weighting (0.5 and 0.5), the soldering iron scores (based upon Table V) are as follows, and not coincidentally concur with our previous result (that Soldering Iron II wins);

Soldering Iron I (Metcal): 29.1*0,5 + 34.08*0.5 = 31.59

Soldering Iron II (Solderite); 32.9*0.5 + 39.85*0.5 =36.38

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