

# Achieving Ultra-Fine Dot Solder Paste Dispensing

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## ABSTRACT

In order to achieve ultra-fine dot solder paste dispensing, both solder material and dispensing equipment have to be optimized. Dispensability of solder paste was evaluated in terms of “dispensing rate”, consistency of dispensing rate, and the stability of dispensing rate with time. Within the given conditions, threshold values for dispensability seem to exist for viscosity, powder size, and metal content. The desired solder paste properties include fine solder powder, low viscosity, low metal content, high flux activation temperature, and a high thixotropic index. Results were obtained for the Archimedes Metering Valve style pump and the Piston Positive Displacement pump. Some of these data were compared to data obtained from a Pneumatic type pump. With the use of a small nozzle inner diameter, a relatively high pressure is desired for better consistency. For Archimedes Metering Valve assembly with a small nozzle inner diameter, a high consistency may be achieved by using a high encoder count and/or a higher pressure. The dispensing rate of Archimedes type pump increases with increasing nozzle inner diameter and increasing encoder count. This relation could allow more flexible control on metering the paste volume dispensed. For piston pump systems, the dispensing rate increases moderately with increasing nozzle inner diameter and increasing pressure. Interestingly, delay time was found to have negligible effect on dispensing rate, consistency, and stability, possibly due to the relatively high viscosity of solder paste materials. Pneumatic dispensing systems are more prone to clogging, presumably due to cold welding developed under cyclic pressurizing of the paste.

Key Words: dispensing, dispensability, solder paste, flux, surface mount, SMT, pump, fine dot, Archimedes, piston

## INTRODUCTION

With the rapid advancement in miniaturization of surface mount technology, it has become a great challenge to dispense solder pastes for ultra-fine dot applications, such as chip capacitors within BGA packages. Failure in dispensing fine dots properly often causes either a significant dispensing machine down time or a very high rework cost. As a result, it is extremely important to establish a solder paste dispensing process able to satisfy ultra-fine dot applications. In this study, the essential elements required to achieve ultra-fine dot solder paste dispensing are investigated, with results discussed below.

## EXPERIMENTAL PARAMETERS

The parameters studied cover both material parameters and equipment parameters, including solder powder size, viscosity, thixotropic property, metal content, flux activation temperature, nozzle ID, pump type (Archimedes

vs positive displacement), pressure, delay time, and encoder count.

### 1. Solder Powder Size

The solder powder used was 63Sn37Pb, with average powder size of 10, 23, 31, and 60 microns, respectively. The 31 microns powder size was utilized in most parameter studies unless otherwise specified.

### 2. Metal Content

The effect of metal content was studied by utilizing the same flux with varying the metal load ranging from 83 to 87 % (w/w). A metal content of 85% was used for most studies unless otherwise specified.

### 3. Solder Paste Viscosity

The effect of solder paste viscosity was studied primarily by varying the flux viscosity. The viscosity of solder paste

was measured at 5 rpm with a TF spindle using a Brookfield viscometer.

#### 4. Thixotropic Property

The thixotropic property of solder paste is determined by plotting log viscosity versus log shear rate using a Malcom viscometer. The slope, typically a negative value, of the line obtained via linear regression is defined as thixotropic index or shear sensitivity factor (SSF). A more negative value of thixotropic index indicates a more thixotropic material. A material with such a property can be sheared thin fairly readily.

#### 5. Flux Activation Temperature

The fluxing strength of a given flux chemistry usually can be reflected by its wetting time, with the stronger flux exhibiting a shorter wetting time. In a practical sense, the activation temperature can be defined as the minimum temperature needed for a flux to function with a wetting time no more than a certain value. Since soldering application could vary considerably from case to case, the choice of criteria becomes a relatively subjective decision. In this study, 20 seconds wetting time was chosen considering that a solder paste reflow process normally would take several minutes. The activation temperature for fluxes was then calculated using equation (1). For each flux the wetting time S at each temperature was determined and plotted against temperature. In general the wetting time S can be expressed as an exponential function of temperature ( see eq. (1) ), with S increasing with decreasing temperature.

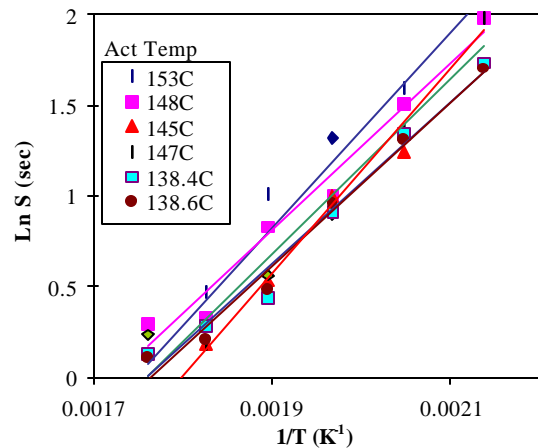
$$S = K e^{A/T} \text{----- (1)}$$

where K and A are constants, T is temperature in degree Kelvin.

The flux activation temperature [1] was regulated by adjusting the activator content of the flux. It was determined with the use of a wetting balance. The substrate material used was copper coupon which was precleaned and then baked at 100 degrees C for 3 hours prior to use. The wetting test was conducted at 195, 215, 235, 255, 275, and 295°C using a 63Sn37 Pb solder bath. The activation temperature for fluxes used in this “activation temperature” parameter study was determined to be 138.4, 138.6, 145, 147, 148, and 153°C (see Figure 1).

#### 6. Dispensing Pump Type

Two types of dispensing pump were used for most of the dispensing test conducted: Archimedes Metering Valve (see Scheme 1) and Piston Positive Displacement (see Scheme 2). The pump was mounted on a XYZ table (Universal Instrument Model GDM4716A). In the case of activation temperature study, a pneumatic type dispensing pump was also used.



**Figure 1** Determination of activation temperature of fluxes by determining the wetting time S at elevated temperatures.

#### 7. Nozzle Size

The nozzle size is expressed as inner diameter (ID) of the nozzle. Since the clearance between the nozzle tip and the board often varies with the nozzle size, it is important to know the actual combination of those two parameters. Table 1 shows the setting used in this work for Archimedes and piston pump. As to the pneumatic pump, the nozzle ID used was 16 mils (400 microns).

**Table 1** Nozzle ID and Clearance used.

Nozzle ID mils (microns)	Clearance mils (microns)
8 (200)	5 (125)
10 (250)	6 (150)
16 (400)	10 (250)
23 (575)	15 (375)

#### 8. Pressure

The pressure on the paste supply line was regulated in the range from 3 to 18 psi for both Archimedes pump and Piston dispense pump. For pneumatic dispense device, the pressure was set at 35 psi.

#### 9. Delay Time

Delay time refers to the time elapse from the end of the paste pushing (piston or Archimedes screw) movement to the beginning of the dispensing headset lifting. It is considered desirable for allowing the paste-flow to stabilize and for the paste to wet to the substrate. The delay time studied ranges from 0 to 30 ms.

## 10. Encoder Count

Encoder counts represent a portion of the revolutions of the Archimedes screw within the material. A relationship exists between the number of encoder counts and the volume dispensed. A small encoder count usually dictates a smaller amount of volume dispensed, as opposed to a large encoder count which dictates a larger amount of volume dispensed. For the pump used in this study, one full revolution of the screw is equivalent to 12800 encoder counts, and is expected to result in a volume displacement of 3.3 cubic mm (with the trough width being 1 mm). The range of encoder count investigated covers from 1500 to 3500.

## DISPENSABILITY EVALUATION

### 1. Dispensing Rate

The dispensability of solder paste was measured in terms of “dispensing rate”. Dispensing rate can be defined as the amount of paste dispensed per unit time. In this study, the dispensing shot frequency was maintained constant, and consequently the dispensing rate is reflecting the dispensing volume.

For Archimedes pump and positive displacement pump systems, the dispensing rate of paste was determined by measuring the total weight of 50 consecutive dots of paste dispensed onto a substrate. The average of 5-8 measurements was used to represent the dispensing rate. For pneumatic dispense system, the dispensing rate was determined by measuring the total weight of 1008 dots at intervals during the dispensing of the entire syringe.

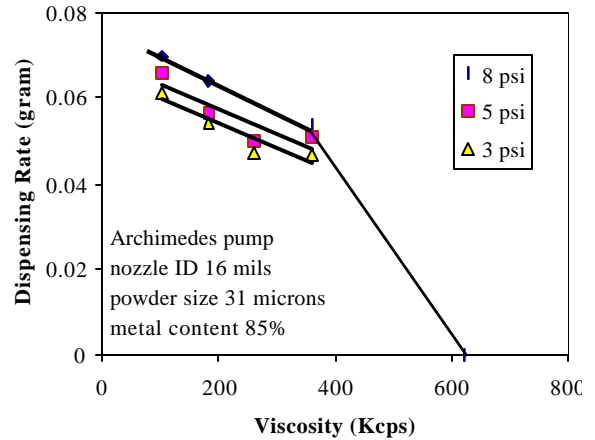
### 2. Consistency of Dispensing Rate

In some instances the consistency of the dispensing rate was also studied. The consistency of dispensing was determined by calculating the standard deviation (SD) of 5-8 measurements, and is expressed as percentage of the average quantity of paste dispensed. The effect of certain variable on consistency was studied by examining the trend of SD variation as a function of the variable.

When two levels of variables, such as viscosity and pressure, were involved in one graphical analysis, the maximum standard deviation (MSD) of the dispensing rate was determined for each fixed value of the secondary variable, such as pressure. The effect of the secondary variable on consistency was studied by examining the trend of this MSD with changing value in this secondary variable.

### 3. Stability of Dispensing Rate

The stability of dispensing rate was determined by monitoring the dispensing rate as a function of time, which was expressed in terms of fraction of paste in syringe being dispensed. This study was conducted on the pneumatic dispensing system and Archimedes pump system. All of the paste tested was packaged in a 30 cc syringe.



**Figure 2** Effect of viscosity on dispensing rate using Archimedes pump.

## RESULTS

### 1. Effect of Viscosity

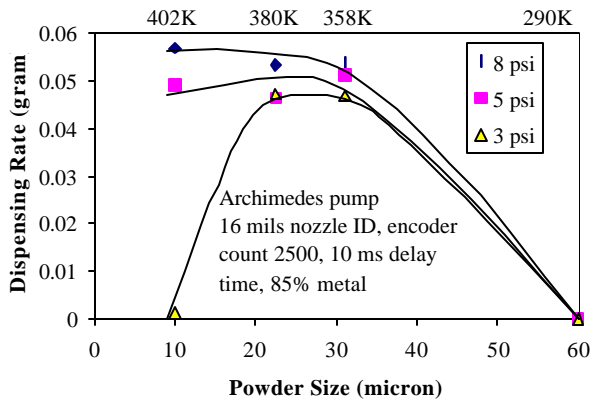
At 8 psi, the dispensing rate decreases almost linearly with increasing viscosity up to about 400 Kcps, then drops rapidly with further increase in viscosity (see Figure 2). At pressure lower than 8 psi, the trend appears to be parallel to that of 8 psi, at least up to about 400 Kcps in viscosity. Apparently, a higher viscosity material will exert a greater resistance against flowing. The abrupt drop in dispensing rate at viscosity greater than 400 Kcps suggests that this 400 Kcps may represent a threshold value in the viscosity. Solder paste with viscosity higher than this value will not flow through the 16 mil ID nozzle at the pressure used in this experiment.

The viscosity, as the primary variable in Figure 2, seems to have a negligible effect on the consistency of dispensing rate. The standard deviation (SD) of dispensing rate scatters with increasing viscosity under any given pressure value. However, the pressure, as the secondary variable in Figure 2, does show a positive effect on the consistency. Thus the maximum standard deviation (MSD) observed is about 2.8%, 1.5%, and 0.5% for pressure 3 psi, 5 psi, and 8 psi, respectively. In other words, the consistency improves slightly with increasing pressure within the range studied.

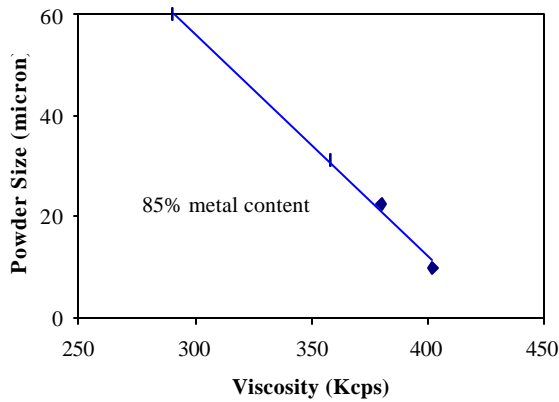
### 2. Effect of Solder Powder Size

At high pressure (8 psi), the dispensing rate decreases gradually with increasing powder size initially, then rapidly drops to zero with further increase in powder size, as shown in Figure 3. Since increasing powder size will result in a decrease in viscosity, as shown in Figure 4, the results above suggest that the dispensing rate decreases with decreasing viscosity. Obviously, this is directly contradicting the trend observed in the previous section,

where it has been shown that the dispensing rate decreases with increasing viscosity.



**Figure 3** Effect of solder powder size on the dispensing rate.



**Figure 4** Relation between solder powder size and viscosity of the solder paste

Heterogeneity Factor

This contradicting behavior indicates that there may be some other factor which overrides the viscosity factor. Perhaps this decrease in dispensing rate can be attributed to an increasing heterogeneity due to an increase in powder size. This heterogeneity, possibly caused by conglomeration of some large particles, may result in local retardation of flow, and accordingly cause a low dispensing rate or even a complete clogging in a small nozzle ID environment. The rapid drop in dispensing rate at powder size above 30 microns suggests that controlling powder size below certain threshold value is critical in maintaining the dispensability. Complete clogging at powder size 60 microns for a nozzle with ID 16 mils (400 microns) indicates that the desired

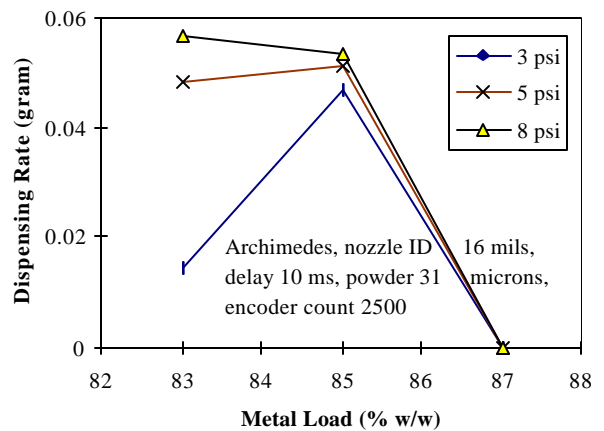
ratio of nozzle ID to powder size should be no smaller than 400/60 (or 6.7).

However, the dispensing rate decreases with decreasing pressure, with the finer powder decreases more rapidly than the coarser powder, as shown in Figure 3. At 3 psi, the dispensing rate of the 10 microns powder drops to nearly zero, and is lower than the other two coarse powders (22.5 and 31 microns). The viscosity of the four paste samples tested is noted at the top of Figure 3. It appears that, although a high viscosity associated with 10 microns paste may contribute to the phenomenon, the viscosity factor alone may not be sufficient to result in this significant drop in dispensing rate. Perhaps some other rheological properties, such as storage modulus (or elasticity), may also contribute to this difference. Earlier work [2] indicates that a higher storage modulus (or elasticity) is found to be associated with finer powder paste. Presumably, this greater elasticity, possibly due to a greater interaction between flux and the large overall powder surface area, may provide more resistance against paste flow under low pressure, and consequently result in a greater sensitivity toward pressure drop.

No trends can be observed between powder size and consistency of dispensing rate. On the other hand, the pressure factor demonstrates a positive effect on the consistency again, with MSD being 67%, 17%, and 0.5% for 3 psi, 5 psi, and 8 psi, respectively.

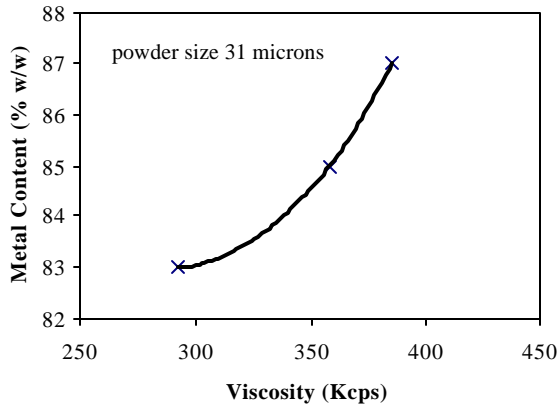
3. Effect of Metal Content

The effect of metal load on dispensing rate is shown in Figure 5. At high pressure (8 psi), the dispensing rate initially decreases gradually, then decreases rapidly with increasing metal content. At a metal content of 87%, the paste can not be dispensed through the 16 mils nozzle due to repeated clogging, and this metal content may represent



**Figure 5** Effect of metal load on dispensing rate.

the threshold value for dispensing under this condition. Since the viscosity increases with increasing metal content, as shown in Figure 6, the decrease in the dispensability can be attributed, at least partially, to the increase in the viscosity. An increase in the heterogeneity with increasing metal content may be another cause for this trend.



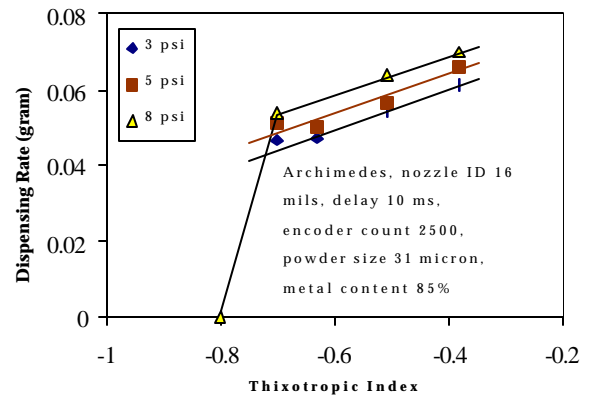
**Figure 6** Relation between metal content and viscosity

However, the relation between metal content and dispensing rate changes with decreasing pressure. The dispensing rate of the 83% metal content paste decreases significantly with decreasing pressure. As a result, at 3 psi the dispensing rate increases first, then decreases with increasing metal content. The cause behind this phenomenon is not clear yet.

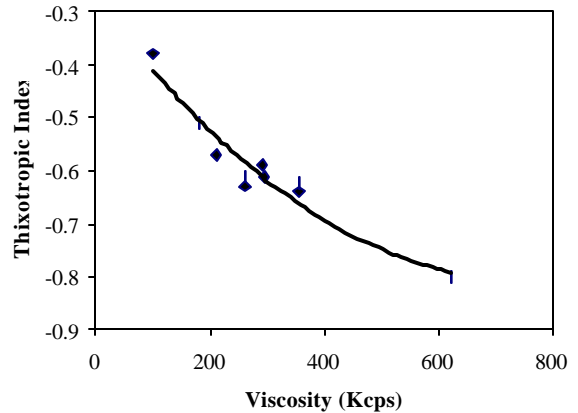
The consistency seems to improve with increasing metal content, as exemplified by comparing 83% with 85% metal content samples. The 87% metal load sample won't dispense without persistent clogging and is not included in consistency trend analysis. The consistency also increases with increasing pressure, as evidenced by the MSD being 150%, 8.3%, and 0.8% for pressure 3 psi, 5 psi, and 8 psi, respectively.

#### 4. Effect of Thixotropic Property

Figure 7 shows the relation between thixotropic property and dispensing rate. It appears that the dispensing rate increases with decreasing thixotropic property (decreasing in absolute value of thixotropic index). However, in this study the decrease in thixotropic property is always associated with a decrease in viscosity, as shown in Figure 8. Since the dispensing rate increases with decreasing viscosity, as discussed in the previous section, it can not be concluded yet whether the change in dispensing rate is



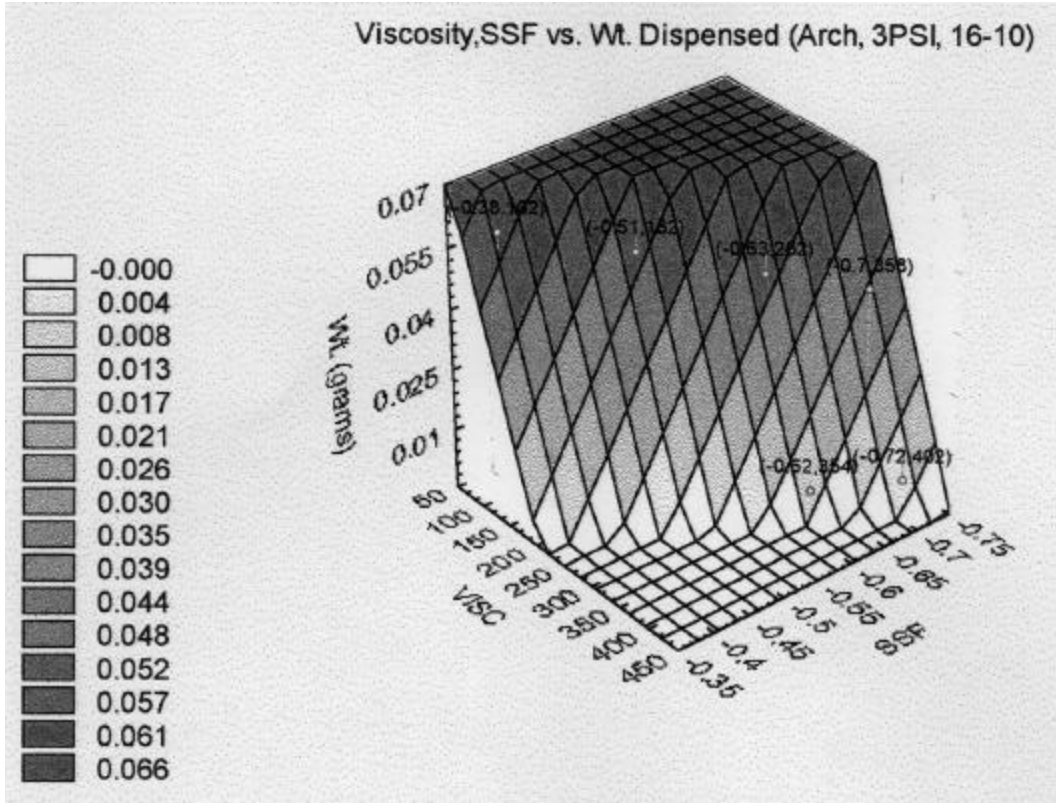
**Figure 7** Relation between thixotropic index and dispensing rate



**Figure 8** Relation between thixotropic index and viscosity

caused by a change in viscosity or thixotropic property by analyzing the 2D graph.

The effect of thixotropic property (also known as shear sensitivity factor, SSF) on dispensing rate is re-analyzed against that of viscosity with the use of a 3D graph, as shown in Figure 9. In this graph, the sensitivity of dispensing rate (expressed as Wt (grams)) toward viscosity and SSF appears to be comparable, and the dispensing rate (Wt value) increases with decreasing viscosity or increasing SSF value (increasing absolute value of SSF, or increasing thixotropy). Solder paste being more thixotropic will shear thin more readily, and accordingly should be easier to dispense through the nozzle. The trend reflected by Figure 9 fully supports this speculation.



**Figure 9** Relation between viscosity, thixotropy (or shear sensitivity factor, SSF), and dispensing rate (Wt) for Archimedes pump with 16 mils nozzle ID and 3 psi pressure, using pastes with 31 microns powder size and 85% metal content.

It was noticed that the paste with low thixotropy tended to show flux separation during storage. The extent of separation increased with decreasing thixotropy. Obviously, this flux separation will result in a decrease in both consistency and stability of dispensing rate.

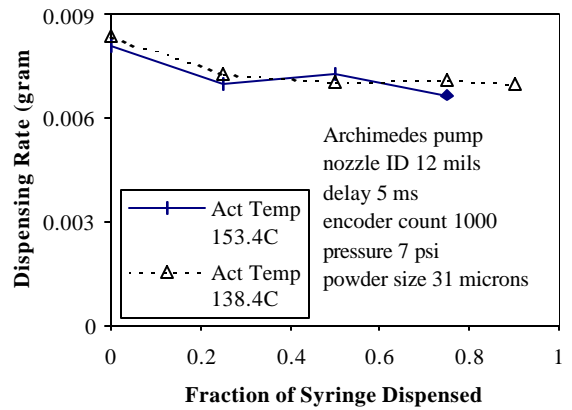
**5. Effect of Flux Activation Temperature**

In an earlier work [1], a “cold welding” phenomenon has been reported for solder pastes with low activation temperature fluxes. For those systems, the flux often removes the solder powder surface oxide and exposes the clean solder surface at relatively low temperature. This will allow the solder powder to cold weld together prior to reflow and form a powder cluster. Since the dispensing process involves pressurizing and shearing the solder paste within the container, solder powder is expected to abrade during dispensing. Accordingly, in the presence of low activation temperature flux, the solder powder may cold weld and result in either a low dispensing rate or clogging.

In order to understand the impact of activation temperature on paste dispensability, solder pastes with various activation temperatures were tested on an Archimedes pump. The dispensability was examined for both dispensing rate and the stability of dispensing rate. Results indicate that

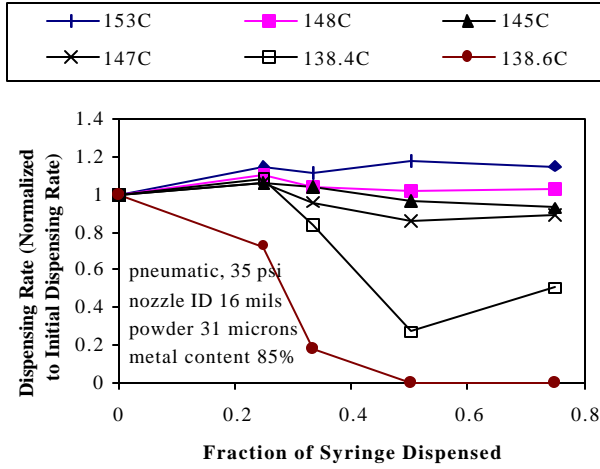
the dispensing rate appears to be comparable, regardless of the difference in activation temperature, as shown in Figure 10. The stability of dispensing rate also remains comparable.

However, a parallel test conducted on a pneumatic dispensing device showed a dramatically different result, as



**Figure 10** Effect of flux activation temperature on dispensing rate using Archimedes pump

exemplified in Figure 11. The dispensing pressure used in this study was 35 psi, and a nozzle with 16 mils ID was used. In this case, paste with a lower activation temperature generally showed a greater declining dispensing rate with time, or a poorer stability of dispensing rate.



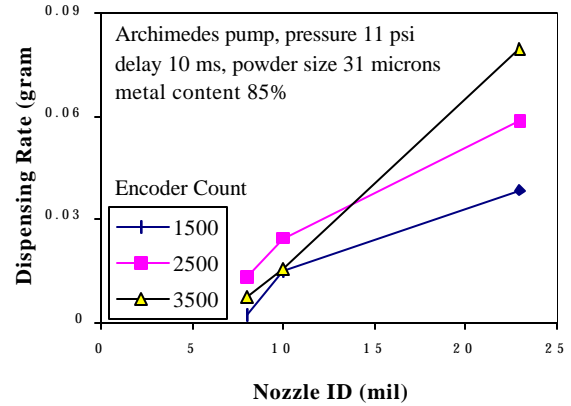
**Figure 11** Effect of flux activation temperature on the dispensing consistency using a pneumatic dispensing device.

The findings from the pneumatic dispensing test indicate that the cold welding mechanism indeed affects dispensability. The difference in the results from the two dispensing tests may be attributed to two factors: (1) pressure, and (2) cycling of pressure. Pneumatic dispensing utilizes a pressure (35 psi) considerably higher than that of Archimedes pump system (7 psi). Although rotation of Archimedes screw may exert some local pressure higher than 7 psi to the paste in the trough of screw, this local high pressure should be relieved once the paste is forced out of the screw. In the case of pneumatic dispensing, the paste is always being continuously cycled under the high pressure before it is dispensed out of the nozzle, consequently had much longer time to develop the cold welding phenomenon.

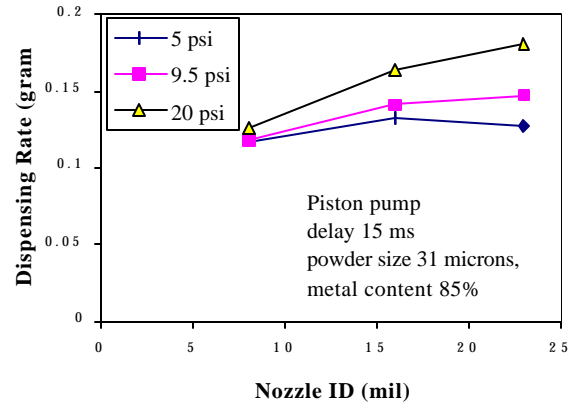
#### 6. Effect of Nozzle Size

The dispensing rate generally decreases with decreasing nozzle size. However, the decreasing rate appears to be a strong function of pump type. For Archimedes pump, the dispensing rate decreases drastically with decreasing nozzle ID, as shown in Figure 12. As to the piston dispense pump, the dispensing rate decreases only moderately with decreasing nozzle ID, as demonstrated in Figure 13. It should be noted that this comparison may be biased by the volume/shot difference for the two process.

Since the paste back pressure is expected to increase with decreasing nozzle ID, the results above indicate that the



**Figure 12** Effect of nozzle size on dispensing rate for Archimedes pump.



**Figure 13** Effect of nozzle size on dispensing rate for piston dispense pump

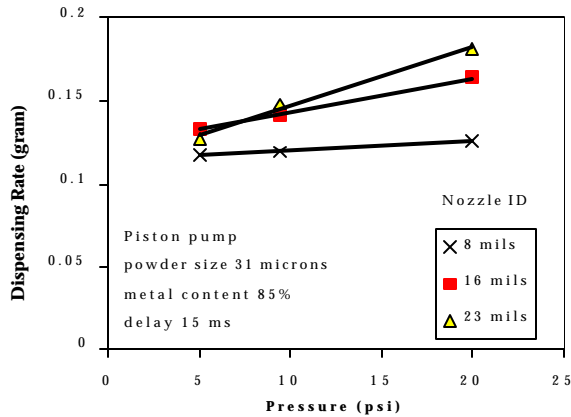
Archimedes paste driving mechanism is more responsive to the back pressure within the range of encoder count tested than the piston dispensing system. This sensitive response of Archimedes pump to the back pressure actually suggests that “control parameters” related to pressure, including nozzle ID, encoder count, and pressure for paste supply line, can all be utilized for metering the paste volume to be dispensed.

Within the scope of this study, the consistency improves with increasing nozzle ID, with Archimedes pump showing a greater response to variation in nozzle size than piston dispense pump.

#### 7. Effect of Pressure

Although generally the dispensing rate tends to increase with increasing pressure, as shown in Figure 14, the effect of pressure on dispensability appears to be affected by

many other factors. Thus for Archimedes pump systems, the pressure may show a moderate effect (see Figure 2 and Figure 7) or a significant effect (see Figure 3 and Figure 5).



**Figure 14** Effect of pressure on dispensing rate for piston dispense pump.

The consistency improves with increasing pressure for Archimedes pump systems, as discussed previously in the section of viscosity, powder size, and metal content factors. This relation indicates that pressure can also be used to regulate and enhance the fine dot dispensing consistency for Archimedes pump systems.

For piston dispense pump, the effect of pressure becomes more profound for large nozzle ID (see Figure 14). This can be attributed to the reduced back pressure associated with the large nozzle ID. Thus, with a reduced back pressure from nozzle site, an increase in pressure at supply line could minimize the back flow of paste during dispensing and accordingly result in an increase in dispensing rate.

Unlike the Archimedes pump systems, internal pump pressure seems to have no effect on the consistency of piston dispense pump systems.

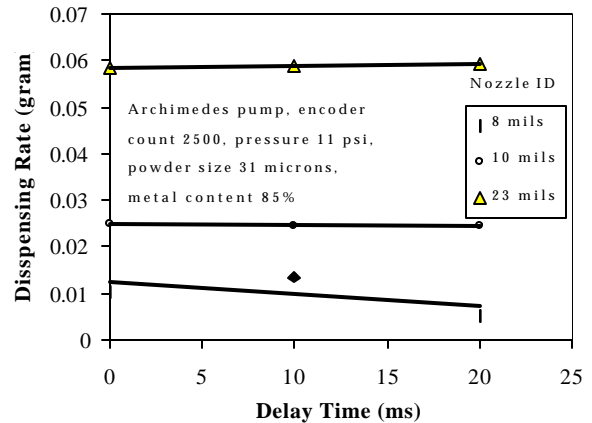
### 8. Effect of Encoder Count

The effect of encoder count on dispensing rate is studied by examining Figure 12. Although some data scattering is quite noticeable near the small nozzle ID end, the dispensing rate in general increases with increasing encoder count. This is expected since the encoder count is supposed to be proportional to the dispensing quantity. The encoder count showed no effect on the consistency. However, the consistency is found to increase with increasing nozzle ID, as evidenced by the MSD value being 7.2%, 4.5% and 0.53% for nozzle ID 8 mils, 10 mils, and 23 mils, respectively.

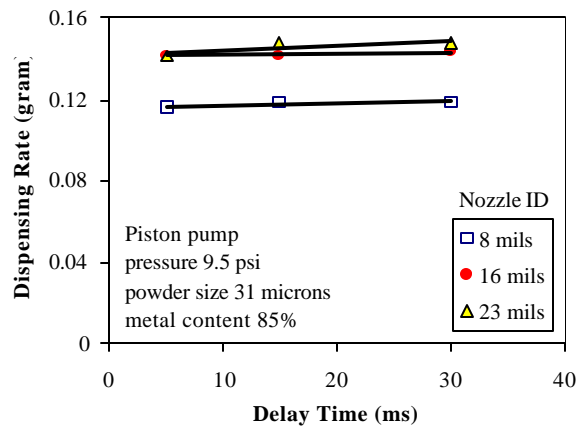
The sensitivity of encoder count effect to small nozzle ID suggests that precise volume control for small dot dispensing may require a careful balance of encoder count to nozzle size.

### 9. Effect of Delay Time

Interestingly, delay time displayed a negligible effect on dispensing rate. This is true for both Archimedes pump and piston dispense pump, as shown in Figure 15 and Figure 16. In the latter case, the dispensing rate increases very slightly with increasing delay time. For Archimedes Metering Valve, with the viscosity of solder pastes being few hundred Kcps, and the trough on the screw being relatively small, the screw may actually serve as a pressure gate. Therefore, probably no paste can be forced through the



**Figure 15** Effect of delay time on dispensing rate for Archimedes pump.



**Figure 16** Effect of delay time on dispensing rate for piston dispense pump.

screw readily from the paste supply line once the screw stops revolution. This may explain the lack of effect on the dispensing rate.

Delay time also showed negligible effect on consistency. On the other hand, the nozzle ID showed a positive effect on the consistency, as demonstrated by the MSD value being 25%, 1.7%, and 0.22% for nozzle ID 8 mils, 10 mils, and 23 mils, respectively for Archimedes pump systems. This is consistent with the discussion in section of nozzle size.

## ULTRA-FINE DOT DISPENSING

In order to achieve ultra-fine dot dispensing capability, the dot size should be small, and the consistency and stability should be maintained or improved. For a high speed dispensing process, both high dispensing rate and high paste placement speed are desired.

Apparently, use of a small nozzle size, together with an adequate clearance between nozzle tip and the substrate, is definitely needed to deliver a small dot size. Enforcing a metered small volume driving movement is also obviously required. Most importantly, a very careful design and tight control of parameters discussed in this work has to be implemented in order to succeed in ultra-fine dot solder paste dispensing. Table 2 shows the parameters as discussed above, the desired direction for delivering a high dispensing rate, and the possible impact on consistency and stability. Recommendations are also proposed for balanced combination in order to achieve better ultra-fine dot solder paste dispensability.

## DISCUSSION

### 1. Solder Powder Size

The powder size value 10, 23, 31, and 60 microns used in the data analysis represent the average value for powder with particle size distribution 0-20, 20-25, 25-37, and 45-75 microns, respectively. This simplification may result in a lower estimated threshold value of powder size for dispensing rate or clogging.

### 2. Metal Content

The dispensing rate versus metal content relation exhibits a peak value when tested at 3 psi. This phenomenon is difficult to explain in terms of rheological properties. Since the standard deviation for dispensing rate for 83% metal load is as high as 150% of the average dispensing rate, the trend plotted may be a skewed one due to the high data scattering rate or noise.

### 3. Nozzle Size

In this study, a nozzle ID of 16 mils was chosen for most of the experiments. This choice allowed the comparison of dispensability of most of the paste samples, including pastes with large powder size, high viscosity, and low

thixotropic index. A choice of smaller nozzle ID would result in immediate clogging of many of the paste samples, and accordingly limit the scope of material parameters to be studied.

### 4. Delay Time

Intuitively, increase in delay time is expected to result in an increase in dispensing rate. The negligible effect observed could be attributed to the relatively high viscosity of metal-filled solder paste materials. The delay time may show a stronger effect on dispensing rate for low viscosity materials such as epoxy adhesives.

### 5. Range

In general, the conclusions regarding the trend or preference for high or low value for any parameters should be confined to the range of value studied for any given parameter.

## CONCLUSIONS

In order to achieve ultra-fine dot solder paste dispensing, both solder material and dispensing equipment have to be optimized. Dispensability of solder paste was evaluated in terms of “dispensing rate”, consistency of dispensing rate, and the stability of dispensing rate with time. Within the given conditions, threshold values for dispensability seem to exist for viscosity, powder size, and metal content. The desired solder paste properties include fine solder powder, low viscosity, low metal content, high flux activation temperature, and a high thixotropic index. Results were obtained for the Archimedes Metering Valve style pump and the Piston Positive Displacement pump. Some of these data were compared to data obtained from a Pneumatic type pump. With the use of a small nozzle inner diameter, a relatively high pressure is desired for better consistency. For Archimedes Metering Valve assembly with a small nozzle inner diameter, a high consistency may be achieved by using a high encoder count and/or a higher pressure. The dispensing rate of Archimedes type pump increases with increasing nozzle inner diameter and increasing encoder count. This relation could allow more flexible control on metering the paste volume dispensed. For piston pump systems, the dispensing rate increases moderately with increasing nozzle inner diameter and increasing pressure. Interestingly, delay time was found to have negligible effect on dispensing rate, consistency, and stability, possibly due to the relatively high viscosity of solder paste materials. Pneumatic dispensing systems are more prone to clogging, presumably due to cold welding developed under cyclic pressurizing of the paste.

## ACKNOWLEDGEMENT

The authors would like to thank Steve Byrch at Indium Corporation of America for preparing the solder paste samples used in this work.

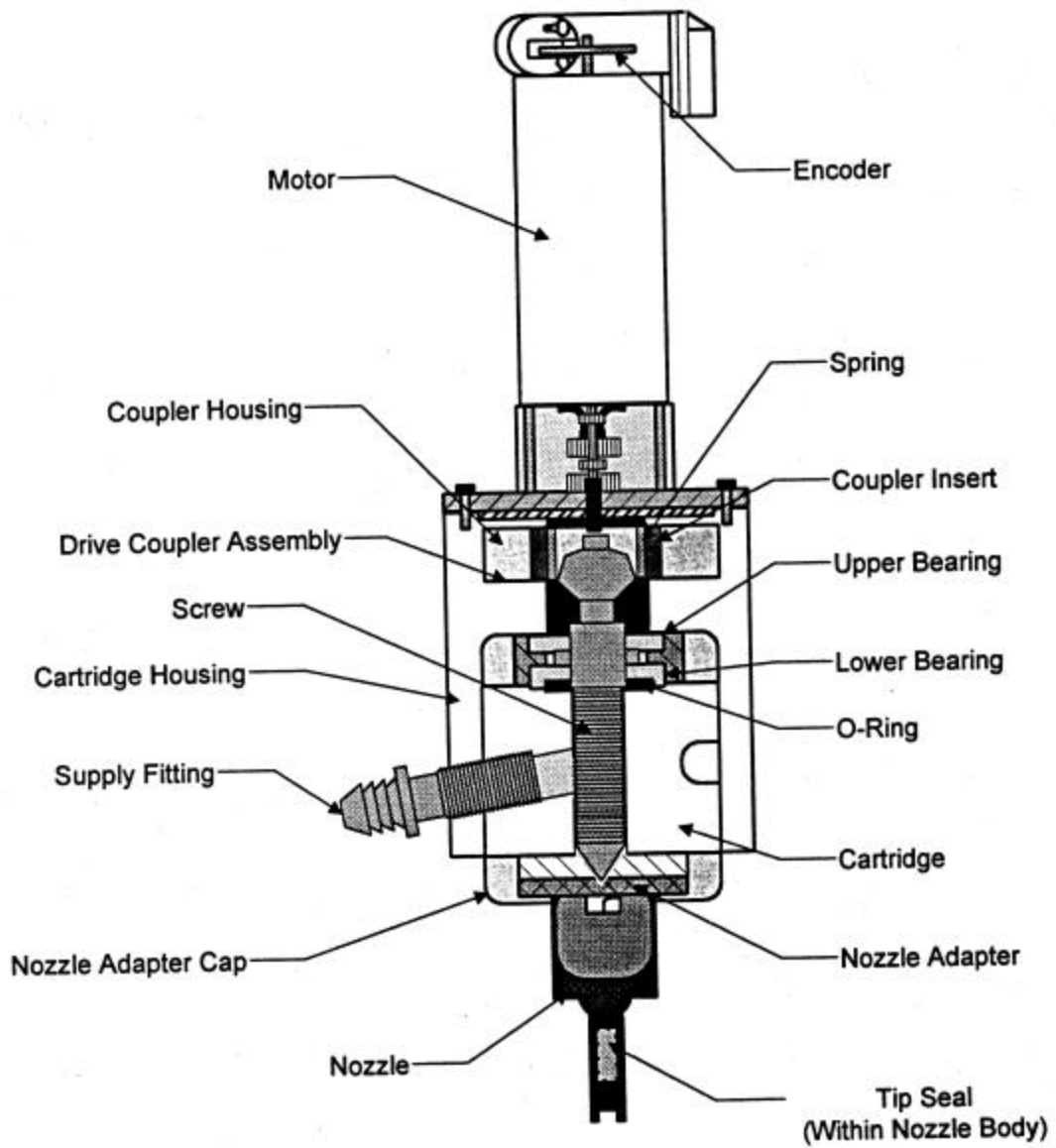
**Table 2** Summary of effects of parameters on solder paste dispensing performance

Parameters	Dispensing rate	Consistency	Stability
Viscosity	Low viscosity needed for high dispensing rate. Threshold value* exists for dispensability.	No observable effect.	Low viscosity tends to result in flux separation and may cause stability problems. High thixotropic property will help to minimize this symptom.
Powder size	Small powder size desired for high dispensing rate under high pressure. Threshold value* exists for dispensability. Ratio of nozzle ID to powder size should be no less than 7.	No observable effect.	Finer powder often has more potential to have poorer stability, due to a relatively larger surface area reacting with flux causing cold welding problems.
Metal content	Low metal content desired for high dispensing rate under high pressure. Threshold value* exists for dispensability.	Lower consistency at lower metal content. High pressure improves consistency.	High metal content may have greater potential for cold welding resulting in stability problems.
Thixotropic property	High thixotropic property desired for high dispensing rate.	Consistency of highly thixotropic paste is expected to be good.	Better stability with high thixotropic property.
Flux activation temperature	Not sensitive.	Not sensitive for Archimedes and piston pump systems.	Stability may be poor under cycling high pressure, particularly for pneumatic dispensing systems.
Nozzle size	Large nozzle size desired for high dispensing rate. Small nozzle size needed for fine dot.	Low consistency for small nozzle ID.	Small nozzle size may be more prone to clogging. Solder paste properties are crucial in achieving stability.
Pressure	Higher pressure results in higher dispensing rate.	High consistency associated with high pressure for Archimedes pump.	Too high a pressure can cause cold welding for pneumatic pump.
Encoder count	High encoder count desired for high dispensing rate. May result in large dot.	High consistency associated with high encoder count. Perhaps a high encoder count with smaller trough dimension would provide a good consistency and a small dot.	Not sensitive.
Delay time	Not sensitive.	Not sensitive.	Not sensitive.
Pump type	Archimedes pump may be more flexible on metering dispensing rate.	Pneumatic pump more prone to have problem.	Pneumatic pump more prone to have problem.

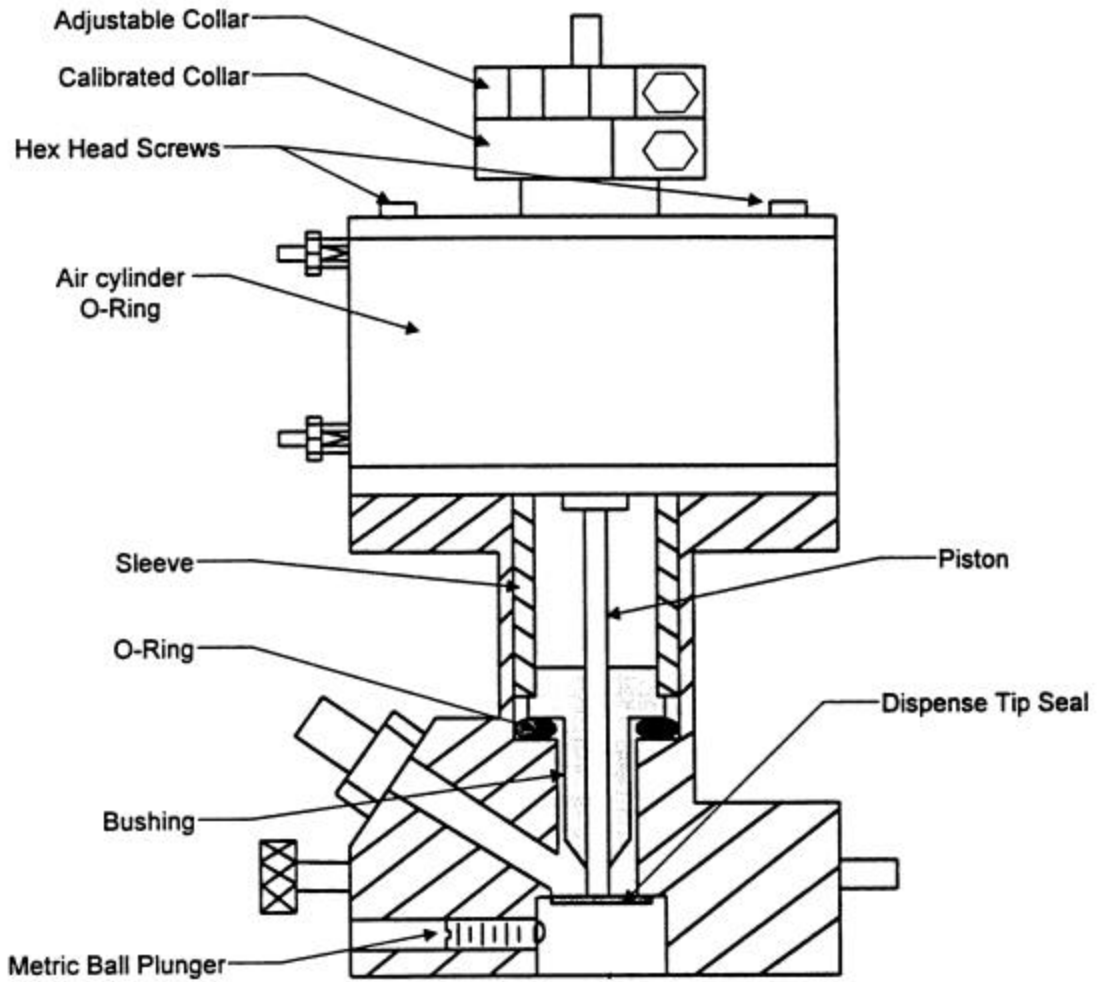
\* Threshold value may be system dependent.

**REFERENCE**

1. W.B. O’Hara and N.C. Lee, “Solder Beading in SMT-Cause and Cure”, in Proceeding of Surface Mount International, San Jose, CA, Aug. 1991.
2. X. Bao, N.C. Lee, R.B. Raj, K.P. Rangan, A. Maria, “Engineering Solder Paste Performance Via Controlled Stress Rheology Analysis”, in Proceedings of Surface Mount International, San Jose, CA, Aug. 1996.



**Scheme 1** Archimedes Metering Valve



**Scheme 2** Piston Positive Displacement Pump