FUSING DICTIONARY – A DIRECTORY OF FUSING TERMS AND TECHNIQUES

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Definitions by BF Entron Ltd., Castle Mill Works, Birmingham New Road, Dudley, West Midlands, UK. Used by permission.

The following are used during the setup and programming of tube fusing cycles on the Currectron III controller:

Function	Definitions	Usage In Joyal Tube Fusers
PSQ – Presqueeze	The time allowed for the electrodes to fully close prior to welding.	Not Used
SQ - Squeeze	The time allowed for the electrodes to fully close and pressurize sufficiently for welding to occur.	Typically 60 – 90 cycles on first program. 10 – 20 cycles on next programs.
W1 – Weld 1	Sometimes called Pre-heat. An initial weld interval typically used to burn off contamination.	Typically not used.
C1 – Cool 1	The time between Weld 1 and Weld 2. It is used to allow the energy from Weld 1 to be distributed more evenly before Weld 2 begins.	Typically not used.
W2 – Weld 2	The main weld interval of the process. Up slope and down slope can be applied during this interval.	Stage 1 – short 10 – 20 cycles Stage 2 – long enough to burn insulation, but not overheat. 20 – 40 cycles. Stage 3 – long enough to fuse. 20 – 40 cycles.
C2 – Cool 2	The time between pulses of Weld 2. It is used to allow the heat to spread evenly though the part by cooling the electrode.	Typically 1/3 to 1/2 of Weld time. Increase for less heat, decrease for less heat.
P – Pulses	The number of times that Weld 2 + Cool 2 are used. The max is 9. Used to lengthen the time that heat is applied.	Stage 1 – short, 1 - 5 pulses. Stage 2 – long enough to burn off the wire enamel, but not overheat. Typically 6 – 9 pulses. Stage 3 – long enough to fuse without annealing the wire. Typically 7 – 9 pulses.

H – Hold	The time following the last pulse before the stage ends. The electrodes stay closed, but no current flows. This allows the electrodes and part to chill down.	Stage 1 – 0. Stage 2 –Typically 10 - 30. Stage 3 – long, so that the part can chill down and not stick to the electrodes. Typically 60 – 90 cycles.
Off	This is used for repeat spot welding, and not for tube fusing. It turns off the welder for a number of cycles so that the part can be indexed.	Always set to 0 for tube fusing.
PV	Sets the voltage which is output to the proportional regulator. This parameter can be programmed in the range of 0V-10.0V which sets the regulator to 10 psi per volt. The force displayed is calculated from the PV setting.	Stage 1 – high, to crimp the connection into the desired shape. Typically 5 to 10 volts. Stage 2 – moderate, to allow fume exhaust and higher resistance. Stage 3 – high, to fuse the part into a tight connection.
Heat 1	Sets the percentage of the heat range for weld1. This parameter can be programmed in the range of 0-99 %.	Typically not used.
Heat 2	Sets the percentage of the heat range for weld1. This parameter can be programmed in the range of 0-99 %.	In CCR mode, this value changes based upon the Current 2 entered.
I1 -Current	This parameter represents the target current required for Weld 1. The current monitoring system, when enabled, compares the actual welding current to the set target current.	Typically set to 0.
I2 - Current	This parameter represents the target current required for Weld 2. The current monitoring system, when enabled, compares the actual welding current to the set target current.	Varies based on connection. 1st Program – low, only enough to allow tube to crimp. No color change. 2nd Program – higher, enough to cause enamel to decompose, but not melt tube. Moderate glow of electrode (NOT WHITE!) 3rd Program – moderate, to fuse but not melt part. Slight glow of electrode.
PHA	Phase Angle Mode. The Current and heat parameters are independently adjustable. No current regulation takes place. The Current parameter is used for monitoring only.	Typically not used. See CCR mode.

CCR	Constant Current Regulation Mode. The current parameter is adjustable, but the heat is determined by the timer, as it regulates the current to the set level.	Typically used for tube fusing, because it controls the current directly and gives more uniform heating.
Normal / Link Program	Normal terminates the fusing process after hold is complete. Link to next program continues fusing using the next numbered program.	Typically three programs are linked. The first is used to crimp the part, the second to remove the enamel, the last to fuse the connection. The first two programs are marked link, the last is marked normal.
Upslope	The time to ramp the current from 0% of Current 2 to full value, in cycles. It helps to reduce arching. This time is included in Heat 2.	1st Stage – short 5 – 10 cycles. 2nd Stage – moderate, 5 – 10 cycles. 3rd Stage – 0
Down slope	The time to ramp the current from 100% of Current 2 down to 0%, in cycles. This time is included in Heat 2.	Typically not used.

LARGE TUBE FUSING PROCESS

Several excellent documents are available detailing the theories of large tube fusing. References to these will be provided in the appendix. Based upon those references and direct experience, we offer the following explanation of the large tube fusing process.

Product Placement.

The first step is to put the tube into the lower electrode holder, and then bring down the upper electrode to hold it in place with a very light pressure. In order to accomplish this, the operator touches both palm buttons within a half second. The PLC commands the weld controller to go to program 62. Program 62 is configured with no heat or current, but with a very low pressure signal, usually in the 2 – 10 psi range. The weld controller sets the pressure low, and then the head is lowered on to the tube or lug without crimping it. No heating occurs in this phase. This allows the operator to insert the wires into the tube if he hasn't done so already. He may also start over by pressing the reset button or select a different connection. Once the operator is satisfied that the part is ready to fuse, he presses the START switch or switches to begin Stage 1.

Stage 1 – Forming

The next step is to form the product for optimum fusing. To do this, we use high force to crimp the tube or lug into a crescent shape. Optimally, there is an even distribution of wires in one or two arcs squeezed between the collapsed tube walls. Poor fusing strength will result from all of the wires bunched directly in the center, or from non-uniform distribution of wires. Optimal fusing results from one or two uniform layers of wire.

Typically, we apply a high pressure, and only sufficient heat to soften the tube walls just enough to deform to the desired shape. Typical weld times are 10 to 20 cycles with one to five pulses. The weld program which performs this function is the one listed in the touch screen PROGRAM field. This program is Linked to the next program number for Stage 2.

Stage 2 – Insulation removal (or Burn)

Removal of the magnet wire insulation is the next step. Heat is applied to heat and decompose the enamel insulation on the magnet wire. To do this, we apply higher current and lower pressure than Stage 1. The lower pressure increases the resistance in the connection during the removal phase, which raises the temperature. The low pressure also allows the fumes to escape the connection more easily.

The process during Stage 2 consists of higher currents than in Stage 2, but not so high that the tube (lug) or conductors melt. This requires a balance between Current2 and the cycle times of Weld2, Cool2, and Pulses such that the current heats the tube up quickly, then pulses on and off to maintain a uniform temperature. The desired temperature is only hot enough to decompose the insulation. Sufficient Cool cycles and Pulses are given to provide time for most or all of the insulation to be vented as fumes. During this stage, some charring of the wires outside the tube may occur, but not a significant amount.

The high current melts the tin to flush out any remaining insulation, and to act as a flux to clean the wires.

This program is LINKed to the next program number for Stage 3.

Stage 3 – Fusing

In Stage 3, the process produces a diffusion weld by forcing the copper surfaces tightly together.

To do this we use a moderate current / high pressure cycle. The moderate temperature maintains ductility of the copper without overly softening it. The high pressure forces the wires and tube together so that surface fusion bonding may occur.

Although we want to melt some of the surface tin, we do NOT want to melt or substantially soften the copper wires. That makes the conductors much more susceptible to breakage and pullout. Tin melts at about 450 degrees F (232 C.), while copper melts at 1981 degrees F (1083 C.) So, we want to heat the part hot enough for the tin to melt inside the tube and flush out any residue from the insulation. But, we don't want to heat the part so much that the copper becomes molten.

The Stage 2 program should be linked to the Stage 3 program. The Stage 3 program will have higher pressure than Stage 2, and equal or lower heating. While it is likely that one or both of the electrodes may glow or incandesce, they should not change to a bright white hot. A low glow is best for both the product and longer electrode life. When the joint reaches the point where the wires have approximately 0.25 inches of burn back (or charring), then the process is probably complete.

At the end of Stage 3, we usually add some Hold time to maintain pressure while the part is cooling. This reduces thermal stress in the product.

Optional Chilling

After the Fusing Stage is finished, we optionally chill down the part and the electrodes. This allows the part to separate better from the electrodes and is easier to handle. The head is kept down, the pressure is reduced to low force, and the air blast is left on.

The amount of CHILL time is set in the SETUP menu of the Touch screen (not the Currectron III). Enter the time in seconds.