Welding to the Power of S^3

by EXEL ORBITAL SYSTEMS INC.

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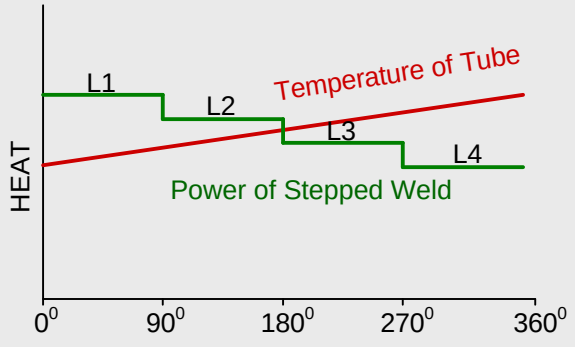
S^3 Welding has been developed by Exel Orbital Systems, Inc. in order to simplify the sometimes very complex task of programming and trouble-shooting multi-level welds. Multi-level welding has been the preferred method of automatic tube welding or orbital tube welding for many years because of its ability to complete the weld in a single 360^0 revolution. The difficulty of creating an orbital weld in a single revolution is as the temperature of the tube increase, while being exposed to the welding arc, the power of the arc must reduced in order to not over penetrate subsequent portions of the weld.

Image 1 , Exel Orbital's EPS-2000 Power Supply

To resolve the problem of the tubes increasing heat the weld is stepped down in power using levels, as shown in Graph 1, below. Since the heat of the tube increases linearly and not in the stepped manner suggested by the downward stepping power of the weld, at least one solution became to increase the number of levels. Traditionally 4 levels were used as shown in Image 2 however, as many as 8 and 10 levels are used in an effort to make the step transitions more smooth.

As a practical matter increasing the number of levels was undesirable, as adjusting the settings for optimum weld bead penetration was extremely difficult. Likewise adjusting the power of 4 levels was also very difficult and hours, even days could be spent in developing the "optimum weld schedule". Knowing which level or combination of levels to adjust to carry the appropriate amount of heat to subsequent levels has become almost an art form. Graph 1 clearly shows that the temperature of the tube increases linearly and steadily while being exposed to the heat of the welding arc. Logically it would stand to reason that the power of the welding arc should be decreased in a manner inversely proportional to the tubes increase in heat. By default this decrease in power mirrors the graph of the tube temperature and is linear and smooth, not stepped. This improved method is shown in Graph 2 and is called S^3, standing for Single Slope Single pass welding.

Another problem with the large steps of a 4 level orbital weld is the sudden change of power causing a thinning of the weld bead at that point. This thinning followed by a gradual widening as again



Graph 1, Linear Heat Graph of Stepped Orbital Weld

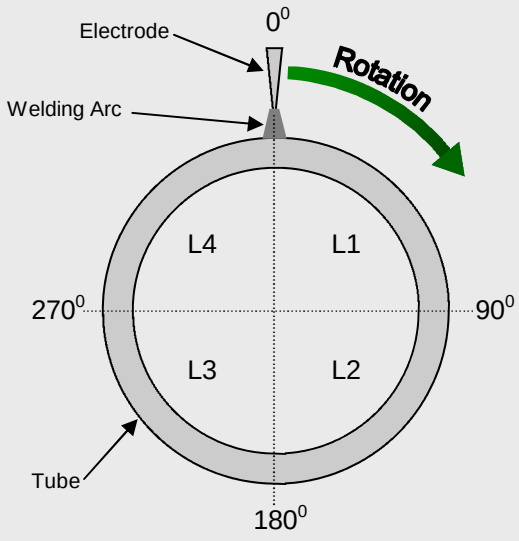
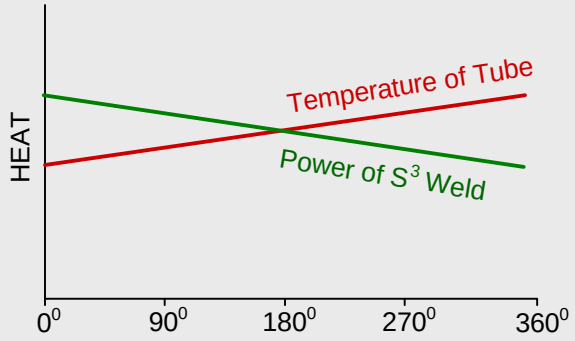


Image 2, Polar Graph of Orbital Weld

the temperature of the tube increases is referred to as a “Christmas Tree Effect”, and its comparison to the S^3 weld is shown in Image 3.



Graph 2, Linear Heat Graph of S^3 Orbital Weld

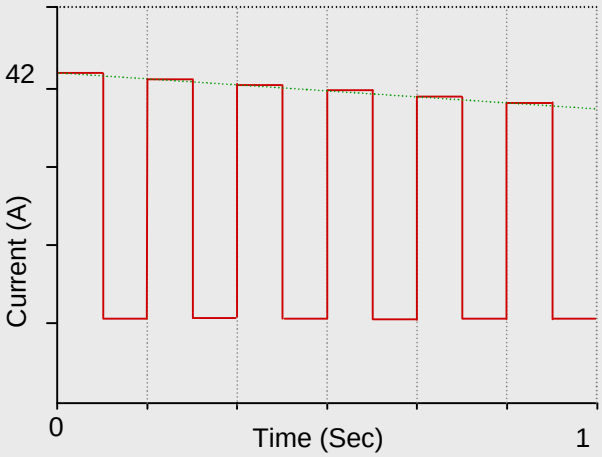
Image 3, Pulsed Weld Christmas Tree Effect vs. S^3

The most common type of weld used in orbital welding is DC pulsed. Given the steadily declining power of the S^3 weld, the most convenient time to reduce power is with each pulse cycle. Given the speed and accuracy of today's microprocessor controlled welding power supplies this is easily accomplished. Graph 3 shows how the weld current is reduced in each pulse of the weld giving the smoothest possible transition to give an average power that most closely matches the inverse of the tubes temperature increase.

The actual number of levels in an S^3 weld could best be described as follows:

$L = Pf \times T$

Where:
L is the total number of levels
Pf is the pulse frequency in Hz
and
T is the total weld time.
Given the weld schedule shown in Image 4 that



Graph 3, S^3 Power Reduction with 6 Hz Frequency

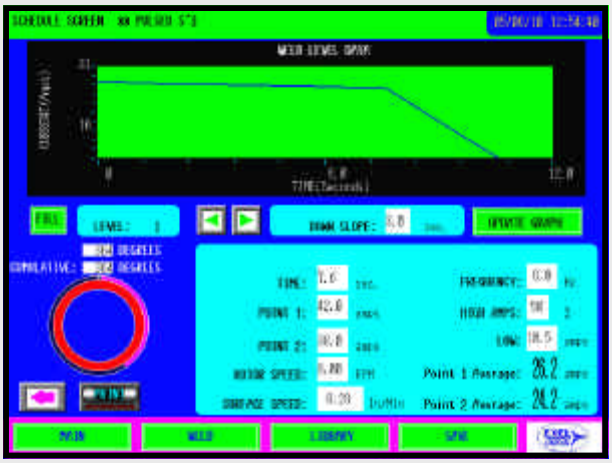
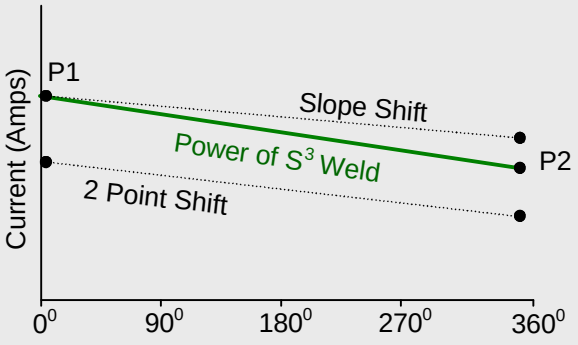


Image 4, S^3 Program on EPS-2000 Power Supply

actual number of steps in the weld schedule is:

L = 6Hz x 7.6 sec.
L = 45.6 Levels

Adjusting an S^3 weld is easy. By changing one or both of the 2 points which describe the S^3 Schedule the entire slope of the line and hence every level associated with it automatically changes as shown in Graph 4.



Graph 4, Adjusting the S^3