PRINCIPLES
OF
SEAMWELDING

AMADA®

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TABLE OF CONTENTS

1. PRELIMINARY:

What follows is a review of some basic physical principles which are related to the industrial process called seamsealing. It is not to be construed as a rigorous analysis, but rather as an aid in achieving a quick understanding of how the several parameters involved in the process will affect the end result.

Used as a guide and method to choose the right values, it could save many man-hours of effort by a shop foreperson, particularly when operating with or without little professional engineering guidance.

2. THE THREE BASIC STATES OF MATTER:

It is a fact of daily observation that ordinary matter comes in three basic flavors, solid, liquid, and gas. It is also a fact of observation that most substances can be made to change from one state to the other. Everybody knows that water, for instance, can be made to go from its normal solid, crystalline structure (this has been written during a New England winter) to a liquid condition (although this condition prevails only over a very narrow temperature range) and finally to a gas, and that these transformations can be achieved by temperature changes.

What everybody has not noticed, however, is that the same changes can be made to happen by changing the pressure and leaving the temperature constant. As a matter of fact, pressure plays as important a role in the melting process (and, therefore, in welding) as temperature does.

At this point, please look at figure #1. It is simply a two-dimensional graph showing how two dimensions (temperature and pressure) determine in which of the three classic states a given substance is.

2. THE THREE BASIC STATES OF MATTER:

The plane of the graph is divided into three areas, namely solid, liquid, and gas. One particular point in the plane is of peculiar importance, and it has been identified in the figure as "TP" which stands for "triple point". Its coordinates represent the only combination of pressure and temperature at which the three states of matter can steadily co-exist with each other in equilibrium. As a digression, life is possible on earth only because our temperature and pressure are normally so close to the TP of water.

To the right to Tc (critical temperature), it is not possible to maintain the substance in any state other than gaseous.

What does all this have to do with welding?

3. WELDING:

Welding, by definition, consists of making a single part out of two, and that is pretty difficult to do when the two parts are solid chunks that won't penetrate each other.

The only alternatives left are to either liquify or gasify the contact area between the two parts and then to bring them back to their normal solid state as one solid piece.

To gasify them would have a number of drawbacks. For instance: from figure #1 we can see that a combination of difficult to handle low pressures and high temperatures would be needed. Also, once the material becomes a gas, it is very difficult to make it stay put where we want it. The gasification of solids to mix them and subsequently return to a solid state is used tin some industrial processes, but not in welding.

3. WELDING:

Liquification is the only alternative left. Looking at Figure #1, notice that the range of temperatures over which the substance will remain liquid becomes wider as the pressure is increased. This means that at higher pressures, the control of temperature becomes less critical and, also very important, that the liquid condition can be achieved with less of a risk of reaching the boiling point and blowing the material away.

4. A BORING BUT NECESSARY REVIEW:

At this point the reader may benefit from reviewing the following high school physics concepts and definitions:

Pressure: Defined as the ratio of the applied force to the size of the area over which the force is applied.

A force quite typical in this process is 20 Newtons (4.5 lbs.). A typical area size for the contact point between the electrode and the part being welded is .5 millimeters (.0196") in diameter or .196mm^2 (.0003 sq. inches) area. The pressure is, therefore, in the order of 103 million Pascals (15,000 lbs.sq. inch), high enough to become an important parameter.

Energy: Capacity of a system to do work, measured in joules (one joule is the amount of work necessary to push back a force of one Newton by one meter or a force of .37 pounds by one foot).

4. A BORING BUT NECESSARY REVIEW:

Power: Time rate of energy delivery, or how fast the work is being done, measured in watts (one watt is one joule per second or, in local units, .37 foot pounds per second). It is very important not to confuse energy with power. This confusion is very common and always snowballs into a total misunderstanding to the welding process.

Heat: One of the many names for the concept of energy. It is measured in joules, as all forms of energy (some older units, now in disuse, include the BTU and the calorie).

Temperature: The degree of random mechanical agitation of the molecules in a portion of matter. It is a consequence of the amount of heat (energy) stored as momentum and elastic forces in moving molecules. When all the molecules come to absolute rest and they stop spinning, vibrating, etc., the temperature zero degrees absolute. This total stopping of all motions happens at a centigrade scale reading of -273°C. Nothing can be colder than that. Although the concept of temperature seems to be very easily understood, most people do not really grasp it in its true meaning. Sentences commonly uttered, such as "the temperature in the vacuum chamfer is 300°." reveal such lack of understanding since, according to the definition of temperature given above, vacuum cannot have a temperature (although the walls of the oven do and the heat is transported to the packages inside by infrared electromagnetic radiation and conduction through the holding trays).

As we have seen, the temperature of a body is a manifestation of the amount of energy stored in the motions of the molecules of the body. It follows then that to increase the temperature, we must store proportionally more energy.

4. A BORING BUT NECESSARY REVIEW:

The factor proportionality is called "specific heat" and is measured in units of how many joules of energy must be stored per gram of mass per degree of temperature change. Thus, $L = K \times \Delta T \times M$

Where:
L = Needed energy (joules)
ΔT = Temperature change (degree centigrade)
K = Specific heat (joules/degree/gram)
M = Mass (grams)

All this is true as long as the material remains in its original state (solid, for example) but a very interesting thing happens the moment it starts changing state (melting, for example).

Until the entire piece has melted, the temperature of the mix stops increasing even though additional energy is being poured in. This extra energy that does not contribute to a temperature increase is called the "heat of fusion" and is measured in joules per gram of material.

In summary, to achieve a melt, we must supply not only the amount of energy necessary to increase the temperature up to the melting point but also an extra amount required to change the state from solid to liquid, without any temperature change. Conversely, when a liquid is allowed to solidify by removing energy from it, its temperature will not decrease until the whole mix becomes a solid mass. Figure #2 graphically depicts these transitions.

Continuing with our "boring but necessary" review of high school physics, let us see now what are the practical means that could be used to deliver the necessary energy to achieve a melt and, thus, a meld, i.e., a weld.

4. A BORING BUT NECESSARY REVIEW:

There are many ways in which energy can be transferred to a system (parts to be welded) and most of them have actually been used in practice, ranging from blow torches, through high frequency sound waves (mostly to weld plastics), laser beams, electron beams and, as it is our case, electric currents.

During the explanations that follow (not to be read by electrical engineers), it would be very useful to the reader to visualize the flow of electricity as if it were the flow of a fluid such as water in a closed circuit according to the model shown in Figure #3.

A few definitions and analogies follow:

Voltage: is the equivalent of pressure differential across the high pressure and the low pressure sides of the circuit. Remember that "voltage" is something that exists across two points and not at one point.

Current: is the equivalent of flow (as in liters per minute) through a conductor. The key word to remember here is "through" as the key word for voltage was "across". Current is the amount of electric charge per second that travels through a circuit. The unit of electric charge is called "coulomb" (think of it as one liter of electricity) and the unit of current is the coulombs per second, also known as "ampere". The analogy with the water circuit now comes very handy: In it, the flow of water will obviously be determined by the pressure differential generated by the pump and by the sum of all the restrictions (internal to the pump and external to it). The relationship is simple:

$$\text{Flow (liters per second)} = \frac{\text{Pressure Differential}}{\text{Restriction}}$$

or in electrical terms:

$$\text{Current (amperes)} = \frac{\text{Voltage (volts)}}{\text{Resistance (ohms)}}$$

4. A BORING BUT NECESSARY REVIEW:

We just introduced a new word: "ohm". A conductor has a resistance of one ohm if it allows the flow of one ampere when a voltage of one volt is applied across it. This relationship is called "ohms law" and it is the cornerstone of the science of circuit analysis.

Let us turn our attention now to what happens to the energy (work) generated by the engine that drives the pump and/or the electric generator in our equivalent circuits.

Energy cannot be destroyed. It can be converted in other forms of it (for example, from solar light into heat into pressurized steam into a moving flywheel that drives a grinding wheel that makes sparks and thus generates light again).

In the case of our water circuit, the energy delivered by the engine will be converted into heat by friction of the water at the restrictions (both internal and external). Note that 100% of the energy delivered to the pump will be converted into heat.

Obviously, the amount of heat per second developed at a given restriction should be proportional to the amount of water being forced through it per second and to the pressure drop across it. In symbols:

Power (energy per unit of time) = Pressure differential
* flow (liters per minute)

Looking now at the electrical circuit and, following the same line of reasoning, we have:

Power (joules per second) = Voltage (volts) x current (amperes)
A power of one joule per second is called a "watt".

4. A BORING BUT NECESSARY REVIEW:

How does all this heat generated in the resistances distribute itself among the different resistors (internal and external).

For one thing, the total heat depends on the sum of the two resistors. The higher the sum, the less current will be able to circulate and thus the total power will be less. However, of the power that does exist, a larger percentage will go to the larger resistor.

This is so because the flow being the same in both (they are in series), the percent of power in each of them will be proportional to the pressure (voltage) across each of them (remember, power = voltage x current).

Manipulating the formulas for ohm's law and for power, it can be demonstrated that:

a. If the external resistor is very large, its power will be very low, because even though it will take the lion's share of the total power, it will restrict the current so much that very little total power will be at play.

b. If the external resistor is very small, its power will also be very low because even through there will be little restriction and the resulting large current will result in a large total power, most of this power will end up in the internal resistor, who now will be the one with the lion's share.

Figure #4 shows the power delivered to the external resistor as a function of its value with respect to the internal one for a fixed generator voltage. As can be seen, the power delivered to the external resistor reaches a maximum when its value equals that of the internal one. In this situation, however, the efficiency is only 50% since the power is equally distributed between both resistors.

4. A BORING BUT NECESSARY REVIEW:

It is important to understand this concept well. Absolute statements such as "the higher (or the lower) the resistance at the weld, the more heat will develop" are most often wrong. What matters is the value of the weld resistance as compared with the internal resistance of the power supply. Also, when considering the internal resistance of the power supply, one must remember to include in it the resistance of all the wiring, buss bars, interface surfaces at the connections, electrodes, etc.

It is now time to debunk two very common misconceptions:

Misconception #1: "The current is what has to be monitored during a weld, since it can be demonstrated that the power is equal to the current squared times the resistance. We must have an amp-meter".

Misconception #2: "The voltage is what has to be monitored during a weld, since it can be demonstrated that the power is equal to the voltage squared divided by the resistance. We must have a volt-meter".

The Truth: Notice that in one sentence the resistance is mentioned as multiplying a quantity and in the next it is mentioned as dividing a quantity. Does the power at the weld go up or down with higher resistance?

The answer is that it depends and that if one notices that the current, or the voltage or the resistance has gone up from the time we welded the previous batch, we still cannot say whether the power has gone up or down at the weld unless we know two of the three parameters. Then, depending on which two we know, we can apply one of the following formulas:

$$P = V \times I = V^2 \ / \ R = I^2 \times R$$

4. A BORING BUT NECESSARY REVIEW:

In short, a volt-meter or an amp-meter are equally useful to tell us that something has changed from the previous batch, but neither one, by itself, can tell is what direction the power has gone, unless we know on which side of the curve in Figure #4 we are.

5. SEAMSEALING BASICS:

Consider an arrangement such as the one shown in Figure #5. The current emerging from one side of the power supply goes through one electrode, through the point of contact between the electrode and the lid, the lid itself, the other point of contact, the other electrode and, finally back into the power supply.

> Note: Part of the current penetrating into the lid from the electrode is diverted to the package and then back to the lid at the opposite edge and does not flow through the center of the lid.

If the wiring and power supply are properly dimensioned, the places of maximum restriction (resistance) in the whole loop are the points of contact between the electrodes and the lid; particularly so if the chamfer of the electrodes is rather sharp.

Remembering our previous discussion about how the power is distributed among all the resistances in the circuit, it becomes apparent that the lion's share of the total heat will be developed at the points of contact.

5. SEAMSEALING BASICS:

5.1 Electrode Shape

A sharper (up to 45°) angle will tend to concentrate the heat at the edge of the package and a shallower angle will distribute it more uniformly in the entire lid and more total power will be needed to achieve a weld. This is so for the following reasons:

a. A shallower angle implies a larger area of contact which, for the same force applied by the electrode, means a lower pressure, thus resulting in a higher melting point of the material for some materials and lower for others and a need for different temperatures (see Figure #1) and thus different energy.

b. The larger area by necessity also increases the size of the molten metal pool, further increasing the need for more energy.

c. The larger area decreases the resistance of the point of contact, thus decreasing the share of the total energy delivered by the power supply that is transformed into heat at the desired point (see Figure #3) and points a. and b. on page 8.

It is very important to realize that the total energy dissipated at the weld may either go up or down depending on which side of the curve shown in Figure #4 one is operating at, but that the amount of waste heat developed in the central region of the lid and everywhere else in the system will definitely go up with a shallower angle.

5. SEAMSEALING BASICS:

5.1 Electrode Shape

Typical values for the chamfer can go from 7° when a very wide weld is desired and the final temperature of the package is not critical, up to 45° when the reverse is true. A typical compromise is an angle of 12° good for most packages.

5.2 Electrode Force

Some of the effects must be already apparent to the reader. When the force is increased, the following happens:

a. The range of temperatures over which the material remains molten becomes wider, thus making the temperature control less critical.

b. The contact resistance is also decreased, thus making a lesser percentage of the total energy available at the weld and a larger percentage is dissipated in increasing the temperature of the lid center, wiring and power supply.

c. A more intimate contact is established between the bottom side of the lid and the package edge and, as a consequence, two things happen:

    1. The heat transfer between the lid and the package increases which helps in melting the surface of the package and in achieving a more homogeneous weld.

5. SEAMSEALING BASICS:

5.1 Electrode Force

2. The small fraction of the total current that circulates through the lid/package interface increases, which tends to decrease the temperature at the center of the lid and to increase the temperature of the package, which helps to create a better weld (but may damage the contents). Butterfly packages, which have leads coming out through glass beads on the sides of the package can be severely damaged by the concentration of current in the metal between the beads and the attendant localized heat. See Figure #6.

d. The cosmetic appearance of the weld improves due to a "troweling" or smoothing effect produced by the higher forces.

5.3 Method of Energy Delivery

There are two basic approaches. In the first and most commonly used one, a continuous train of energy (heat) pulses is delivered to the package at a rate of 120 pulses per second as the package moves at a steady speed under the rollers. In the second method the package is stationary while a short burst of pulses is delivered and then, after a cooling time, the package is moved to where the next stitch is to be made.

The users can select which method is to be used by choosing between a Benchmark program of the "hermetic" series (first method) or the "cool" series (second method).

5.3.1 "Hermetic" Method - See Figure #7

As can be seen from the figure, only one heat pulse is applied for each stitch. If the pulses are of the proper "strength" and the speed of the package is properly selected, each nugget will be wide enough to overlap with the next one, which will be generated only 1/120 of a second later.

There will be more on the matter of nugget size when we discuss the power control system, but at this point it should also be noted that the pulses are not infinitely short and from the beginning to the end of an individual pulse, the package can move a considerable distance, thus "smearing" the pulse over that distance.

5.3.2 "Cool" Method - See Figure #8

To begin with, using the "cool" software, the package no longer moves in a continuous, uniform manner as the weld proceeds but rather the motion is of the "hurry up and wait" kind. The power is applied as a burst of several pulses on the same spot of the package while it is stationary.

The result is that the shape of the nugget changes. The width tends to decrease (or remain the same, depending on the power level) and the depth increases for better penetration and different metallurgical properties due to the increased time that the materials remain liquid.

5. SEAMSEALING BASICS:

5.3.3 Which of the two methods to choose?

In general, the "hermetic" software method is preferred for the "average" package. "Average" means: Kovar™ or stainless steel package and lid, unplated or gold-plated or electrolytic nickel-plated, stepped lids of about .005-.007 (inches or meters scale?) thick at the edge. Solder seals are also best handled by hermetic.

The "cool" software is ideal for situations in which the contents of the package are exceptionally sensitive to heat, since by programming an adequate wait time between bursts, the temperature of the package can be held at very low values.

Other situations in which "cool" is the method of choice arises when the lid is thick (>.01") because the more prolonged application of power to each spot allows to bring the lid/package temperature to the proper level despite the lid thickness.

"Cool" is also beneficial when welding electroless nickel-plated material because the molten condition at a given spot can be maintained long enough for the phosphor impurities present in electrolytic nickel to diffuse or alloy with the surrounding material. Phosphor in electrolytic-plated welded parts has been shown to be a major cause of failure due to embrittlement. In the same series of experiments, it was also shown that high, prolonged temperatures at the spot allow overcoming the problem.[1]

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[1] For Further information on this problem and its solution, see "Welding Large Hybrid Metal Packages, Part I" by N. R. Stockman and C. J. Dowes, published in The Welding Institute Research Bulletin of February, 1984.

5. SEAMSEALING BASICS:

5.4 Power Control

In our review of how electrical energy can be converted into thermal energy, we considered only the case of a direct current, that is to say, a current that flows all the time in the same direction.

Actually, in most applications (including seamsealers) alternating current is used, that is, a current that changes direction periodically. In our particular case, the change of direction is synchronized to the power line (in the U.S., 60 changes per second). The fact that we are using AC instead of DC does not change any of the concepts explained so far.

Please refer to Figure #9 and remember that the power was equal to the product of voltage times current. Since the voltage and current have the same sign (in this type of circuit) at all times, and remembering from elementary school that the product of two numbers with the same sign (regardless of the sign being positive or negative) is always positive, the power ends up being always positive too.

The important concept to grasp here is that even though the voltage and current change direction 60 times per second, the energy flows always from the generator to the load and that this flow presents 120 peaks per second instead of 60.

5. SEAMSEALING BASICS:

5.4. Power Control

In some types of circuits (called "capacitive" or inductive" and, collectively "reactive"), the current is not in perfect phase with the voltage, which results in the voltage and current not having the same sign all the time. What happens then is that (for part of the time), the product of both acquires a negative sign.

Negative power? All it means is that during that portion of the cycle, the load is returning back to the generator part of the energy previously delivered to it and that it could not convert into heat (or light or mechanical motion, etc.). In our particular case the voltage and current are in almost perfect phase, and we shall consider our circuit completely non-reactive.

Let us see now exactly how we control the amount of energy deposited at the weld.

From our previous review of physics, we remember that the word "power" meant how much energy was being delivered per unit of time. From this, it follows that the energy delivered by each pulse is the product of power X time (???) during which the power is on or, from elementary geometry, the area under the power curve in Figure #9.

It follows, then, that if we want to control the energy delivered by each power pulse, what we must control is the area under its curve, and then that could be achieved by controlling its height, its width or both.

5.4. Power Control

Actually, there is a very easy to implement circuit that allows controlling both the height and the width simultaneously. It is called "phase control" circuit and uses circuit elements called thyristors.

Please turn your attention now to Figure #10 in which two power pulses corresponding to one voltage and current cycle out of Figure #9 are shown enlarged. What our "phase control" circuit allows us to do is to actually disconnect the load from the generator from the beginning of the voltage semicycle for a time T_{off} and then to connect it back during a time T_{on} repeating the process again in the next semicycle and in all those that follow at a rate of 120 connections and disconnections per second. Thus, when the computer asks the user what percent of power to apply, the user's answer determines the ratio T_{on}/T_{off} and, therefore, how much energy will be delivered at each stitch.

In the cases where software "cool" is run, the energy deposited at each stitch is the product of the number of pulses and the energy per pulse selected by the operator. As we said before, with "cool" there is a cooling time without power before the package is moved to the next stop (spot, stitch).

When software "hermetic" is used, something else happens which is worth noting:

Assume that the package is moving at one inch per second and that the T_{on}/T_{off} ratio is set to .5. Since $T_{on} + T_{off} = 1/120$ second, $T_{on} = 1/240$ second. In 1/240 second, the package will have moved 1/240 inch (i.e., a little over 4 mils). The result is that the stitch is elongated by that amount, thus taking an ellipsoidal rather than circular shape.

5. SEAMSEALING BASICS:

5.5 Speed Control

5.5.1 "Hermetic" Software Method

As the reader will remember from previous pages, this method delivers a continuous train of pulses of adjustable width and height with a fixed spacing between pulses of 1/120 second. Changing the speed of the package has two basic consequences:

a. The distance between centers of the stitches increases with package speed in a simple relationship:

   d(inches) = package speed (inches/second) x 1/120 seconds

b. The longitudinal size of each spot also increases, but in a more complex manner, since now there are more factors to consider. For one thing, as explained at the end of paragraph 5.4, the pulse stretching effect of the package speed tends to make the nugget wider, but only if the energy delivered by each pulse is still enough to melt the extra amount of material. If it is not, the nugget dimensions may even decrease at higher speeds.

5.5.2 "Cool" Software Method

In this method the package is stationary while the power is applied and then it moves at maximum speed to the next spot. Even though the average speed is under user control by specifying longer or shorter cooling times, the distance between and the size of the nuggets will not be affected by the average speed.

5.5.2 "Cool" Software Method

In this method the distance between the centers of consecutive nuggets is the result of specific user entry in mils via the keyboard. The size of each nugget is a direct result of the energy delivered to it, which is determined by the user inputs for power and number of pulses per stitch.

6. HOW TO DEVELOP A WELD SCHEDULE:

By now the reader, without previous experience or theoretical knowledge, may be wondering how can one juggle all these variables to obtain a combination that works. The answer is: By strictly adhering to a method. The golden rule of this method being "Change only one variable at time" and the silver rule being "Don't deviate from your planned tests, no matter what".

In what follows we will assume that the user has no idea of which combinations might work. If she does, the method itself will not change, but the number of wasted test packages will go down.

6.1 Parameter Combinations

From our previous paragraphs we know that the most important parameters are power, speed, and electrode force. For the purposes of this discussion, we will assume that things like which software to use and electrode chamfer angle have been decided beforehand. If they haven't thaw add these additional variables to the three others. The three variables can be visualized as the three dimension of every day perception. See Figure #11.

6. HOW TO DEVELOP A WELD SCHEDULE:

6.1 Parameter Combinations

In the figure, the volume of space of all possible combinations define a hexahedron volume of value Np.Ns.Nf, where Np, Ns, and Nf are the number of different values to be tried for each parameter.

Unfortunately, the number of samples increases very fast every time one wants to try just one more value of any parameter. In the example of Figure #11, where we show three different values for each parameter and thus 27 combinations, we would need 36 samples to test just one more power level.

Experience and common sense help to decide what range of values to try for each parameter. It would be ridiculous, for example, to try zero power.

Now that we visualize the combinations in three dimension, let us slice the hexahedron in a series of slices. Within each of these slices, one of the parameters remains constant. In the example of Figure #12, we have sliced the volume in horizontal planes, which results in three charts, each one of them having all the combinations of power and speed for a fixed electrode force.

After a careful QC and cleaning of the experimental parts and, most important, after making sure that all the oxygen in the glovebox has been replaced by a dry inert gas[1], all the parts should be welded in one session without testing them until they are all welded.

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[1] The presence of oxygen is extremely deleterious to welding, particularly in non-gold-plated parts. Results obtained in an oxygen rich atmosphere can be very misleading.

6. HOW TO DEVELOP A WELD SCHEDULE:

6.1 Parameter Combinations

The leak test results should be tabulated in a form similar to the one shown in Figure #12 and those boxes that pass the acceptance criteria should be visibly identified as in our example.

The next step depends on which one of the following criteria is to be applied.

a. Maximize the number of parts that will satisfy the minimum requirements, even if the parts just pass. Typical optimum cost manufacturing criteria.

b. Obtain some "super" parts although the total yield might not be very high. Typical of some very low volume state-of-the-art research projects.

If Option b. is the case, we would pick the combination that shows the part with the least leakage and never mind the scrap. In the much more frequent case where the criteria is to maximize the number of shippable parts, we will use a system of merit points as follows:

a. Assign to each power level as many merit points as acceptable parts were obtained with it regardless of speed and force.

b. Assign to each speed level as many merit points as acceptable parts were obtained with it, regardless of power and force.

c. Assign to each force as many merit points as acceptable parts were obtained with it, regardless of speed and force.

6. HOW TO DEVELOP A WELD SCHEDULE:

6.1 Parameter Combinations

Now pick the power, speed, and force with the most merit points and call the combination "preliminary schedule #1" with 24 merit points in the example. But the job is not complete yet. Looking again at Figure #12, we see that on either side of the optimum speed and force, the merit points decrease symmetrically from 8 to 5, but that the same is not true around the optimum power.

When a situation like that is noticed, the experimenter should immediately suspect that a "better" optimum might be found a little to the side of the temporary one already found. If a true optimum is desired (and if enough test samples can be made available), a new chart should be developed to explore the region of interest in more detail.

In our example, the region of interest would be between 40-50% power. In real life it very seldom happens that in determining the "preliminary schedule #1" any of the temporary optimums is so well-centered as the speed and force were in our example. Almost always the neighboring areas of all three optimums need a refining exploration to determine a "preliminary schedule #2".

Once the "preliminary schedule #2" is selected, it has to be put to the test by running a number of packages all with the same schedule.

6. HOW TO DEVELOP A WELD SCHEDULE:

6.1 Parameter Combinations

At this point, it is advisable to proceed with caution. Run only ten packages at a time before testing them. Only if the results are satisfactory, run 20 more and so forth until a statistically significant number has been processed.

The definition of "statistically significant" is beyond the scope of this article, but in any statistical quality control handbook there are formulas that permit the calculation of a function called "correlation test" which allows the evaluation of the probability of having a given result (good or bad) due to sheer chance. The idea here is to run enough samples to bring that probability below the maximum specified by the process engineer. Although the derivation of the formulas is beyond the high school level, their application is at the elementary school level, requiring nothing beyond the use of roots and powers.

7. NEST

7.1 Mechanical: The computer is capable of a positioning accuracy of .0005" with a repeatability of .0001". In order to take proper advantage of this capability, the nest must be built correctly.

Of particular importance is that the geometric center of the package must coincide with the center of rotation.

7. NEST

7.1 Mechanical:

The center of rotation is not necessarily the center of the next but rather the center point between the locating pins. This can be easily visualized by imagining a nest made of a piece of stock with a completely irregular and off-center periphery. The nest would still work perfectly if it located the package exactly in the midpoint between the locating pins.

The immediate result of a nest whose dynamic center of rotation does not coincide with the center of the package is that one particular corner of the package tends to be under-welded and others over-welded.

The corollary of this is that the machinists who make nests, must be instructed not to use the outer edge of the nest to find the center of the package cavity as they would normally tend to do, but to make the holes for the locating pins first and then make the cavity for the package.

7.2 Thermal:

In most cases, the mass of the nest is many times larger than that of the package. From the standpoint of the package, the nest is almost an infinite heat sink.

This can be very good or very bad depending on the circumstances.

In most cases it is desirable to utilize the heat sinking capabilities of the nest to keep the bottom of the package (and thus the electronics inside) cool. This is accomplished by designing the nest so as to provide the best thermal contact with the package and by making the nest of a material of high thermal conductivity, such as aluminum.

7. NEST

7.2 Thermal:

In other cases, such as with ceramic packages, it is not a good idea to keep the bottom of the package too cool.

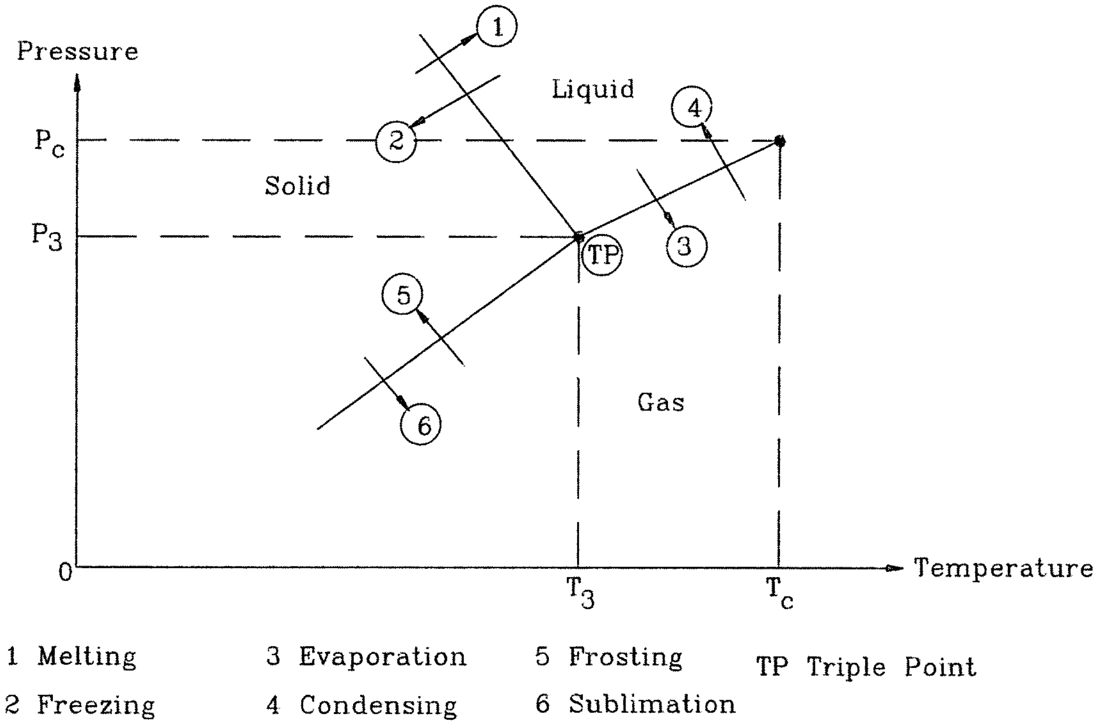
This is so because since the top of the package still has to reach the melting point of the seal, the difference in temperature between the top and bottom may become so large across such a short distance that the differential expansion could crack the ceramic.

In these cases it is better to make the nest of a material with a lesser thermal conductivity, such as fiberglass-epoxy composites as used in the manufacture of printed circuit boards. An ideal material for this application is commercially available as "G-10".

8. CLOSING REMARKS:

It is impossible to condense in this short chapter of users manuals the entire world of electronic and mechanical engineering, physics, math, metallurgy, etc. that has a bearing in joining two metals together. This writer apologizes for the lack of technical elegance, coverage and rigor. The empiric, non-theoretical approach was taken with the idea of reaching the largest possible audience of seamsealer operators. The engineers can always go to their college textbooks, but we thought that the people that spend eight hours a day with their noses glued to the drybox window and their hands stuck in uncomfortable rubber gloves could use a little help.

In any case, remember that Benchmark Industries is always willing and able to lend a hand. Give us a call if you think we can help.



Note: The slope of the boundary between liquid and solid changes with the specific substance, and it may even be reversed for some alloys.

Figure 1
Liquid–Solid–gas
Phase Diagram

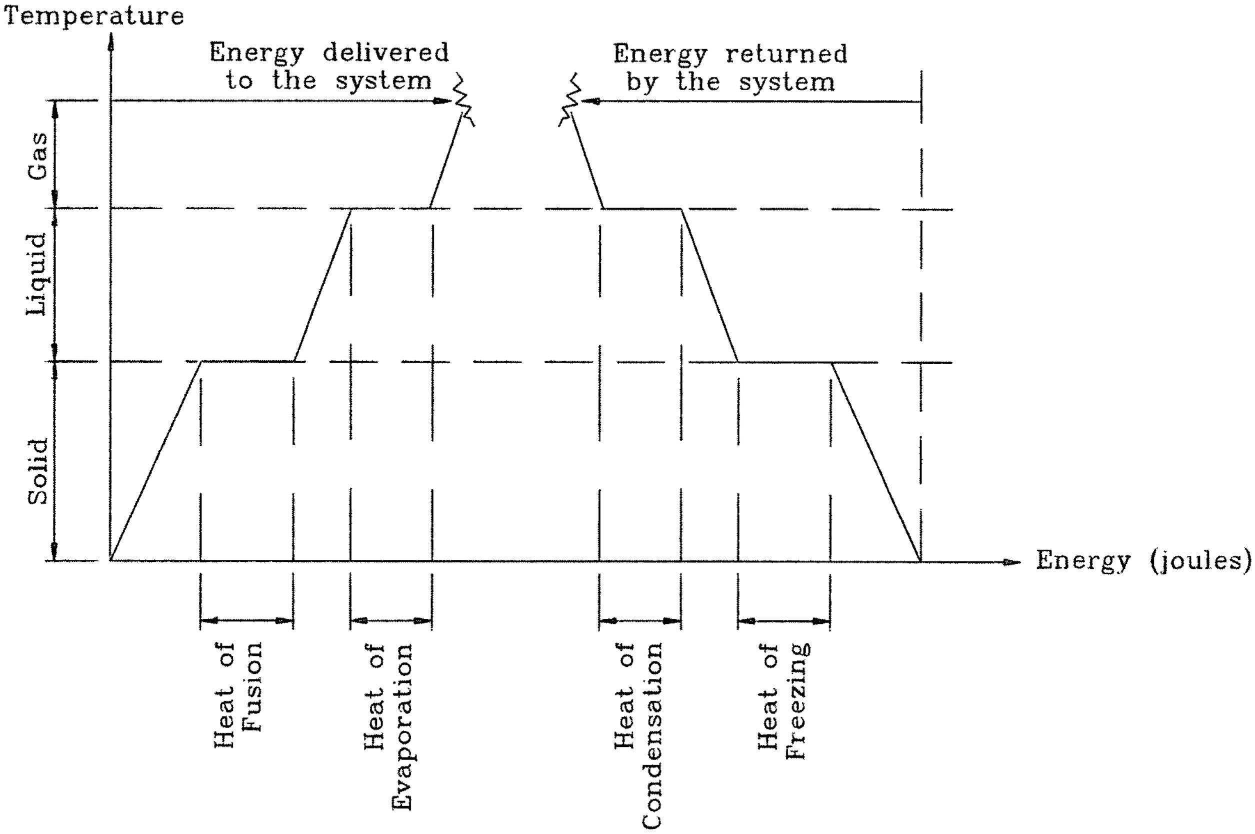


Figure 2
Heat (energy)–Temperature–State
Relationships

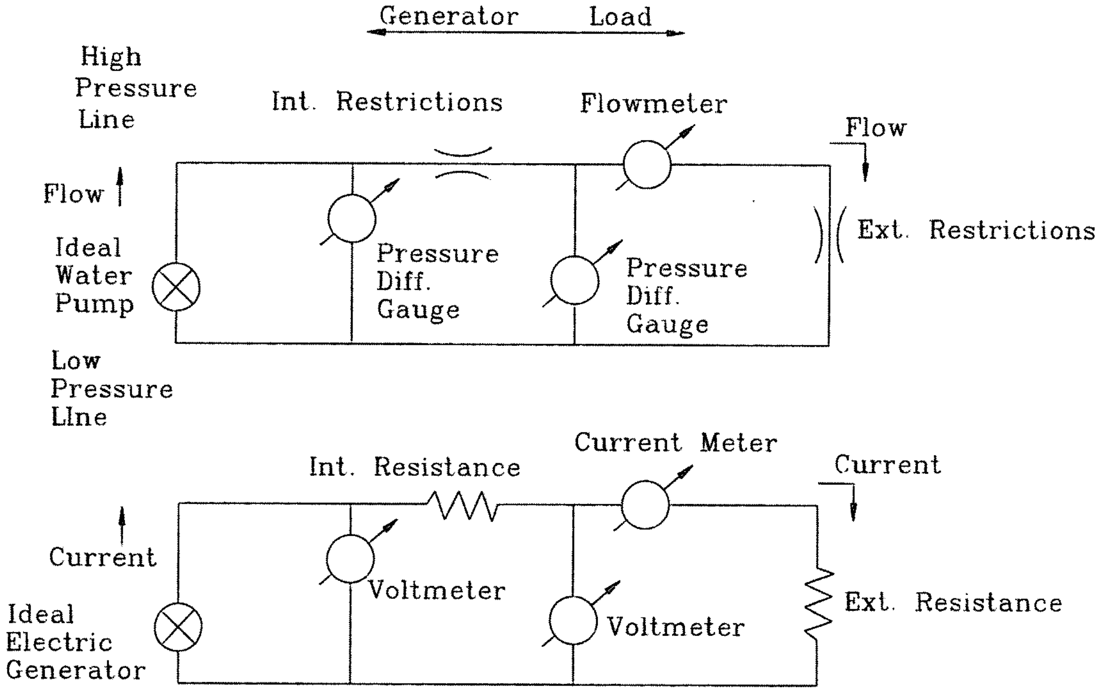


Figure 3
Hydraulic/Electric Analogy

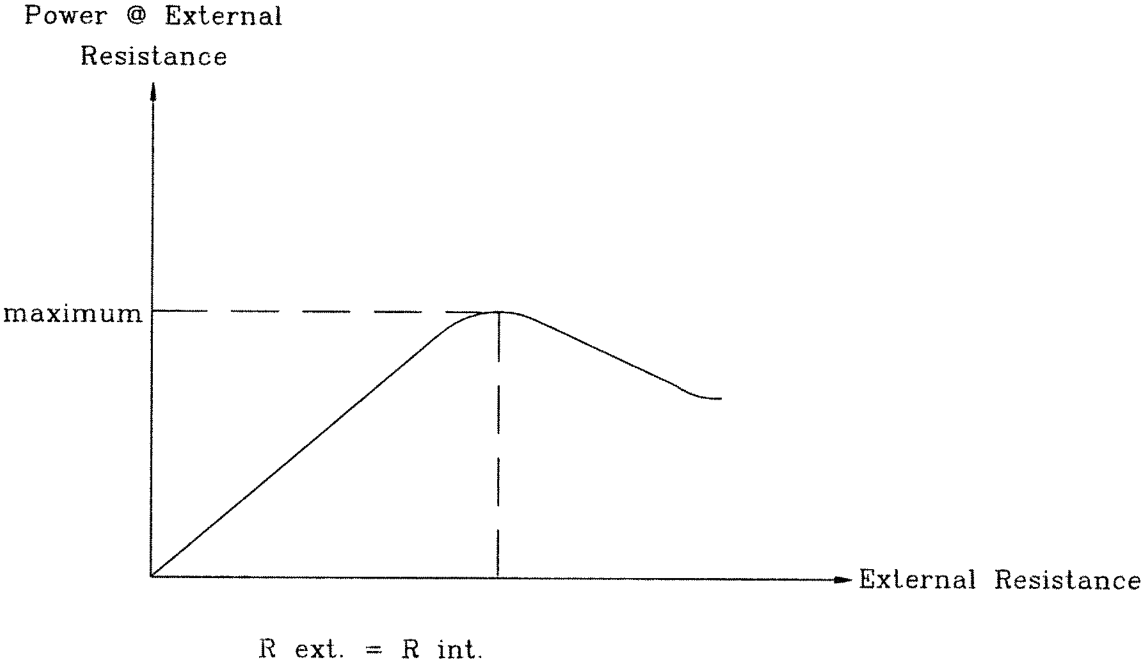
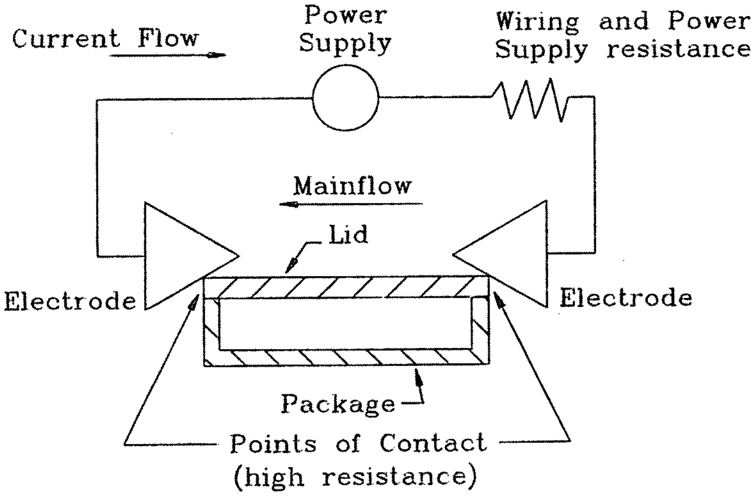


Figure 4
Power Developed @ R ext.



Note: The package moves in a plane perpendicular to the figure.
Of the total power delivered by the power supply, part is transformed into heat inside the power supply itself, part in the wiring, part in the lid mass, and part at the point of contact between the electrodes and the lid, where the melt occurs.

Figure 5
Seamwelder Sketch

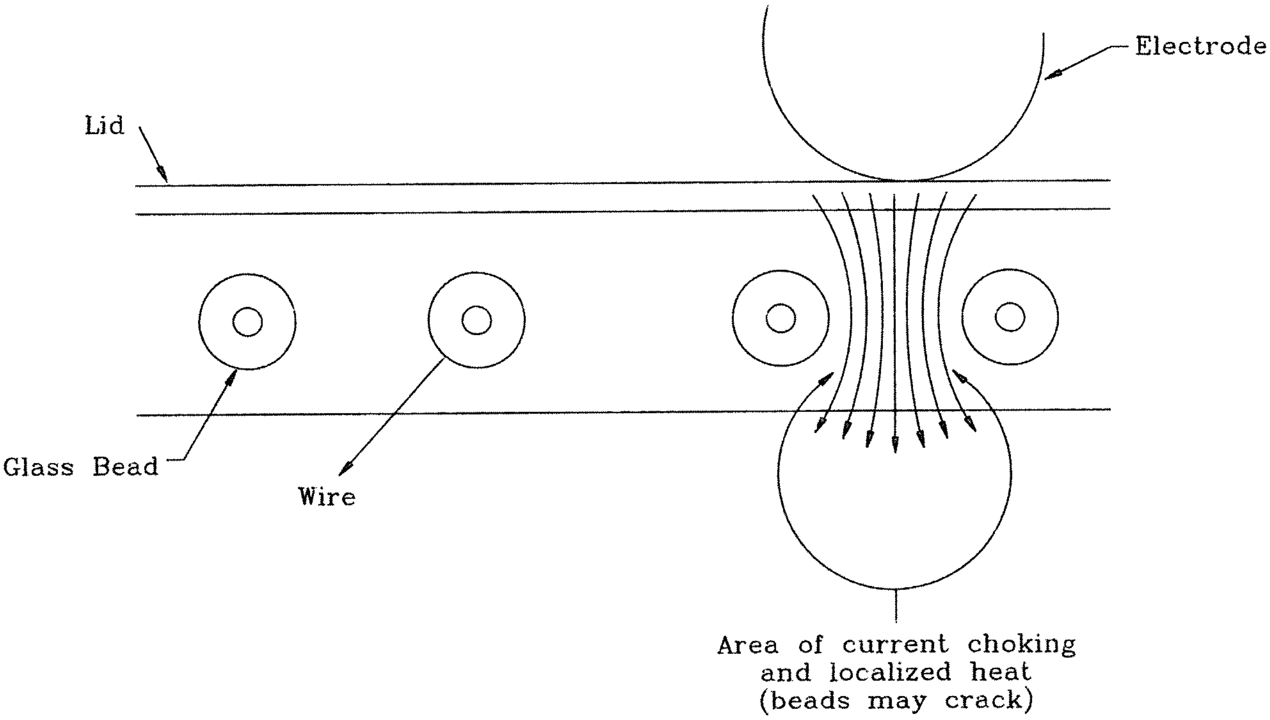


Figure 6
Current circulation in package walls

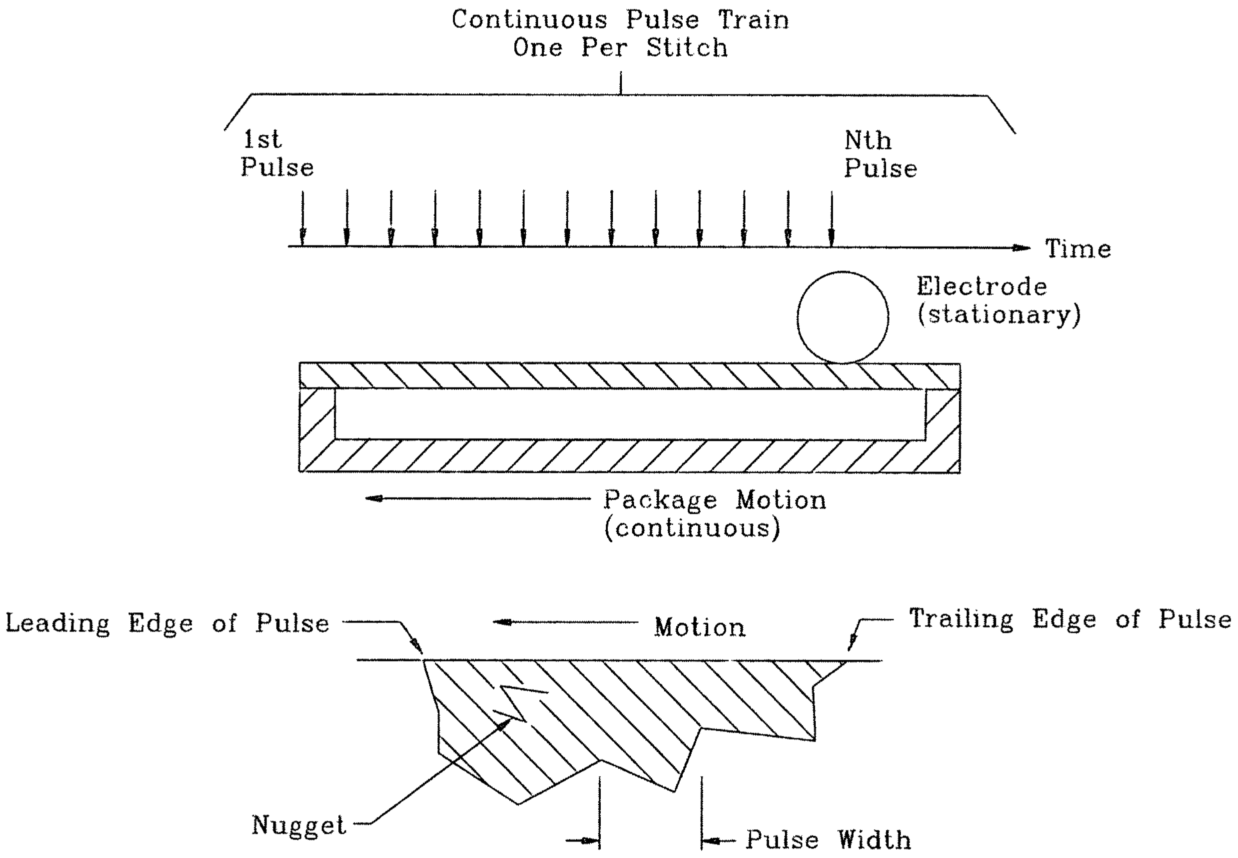
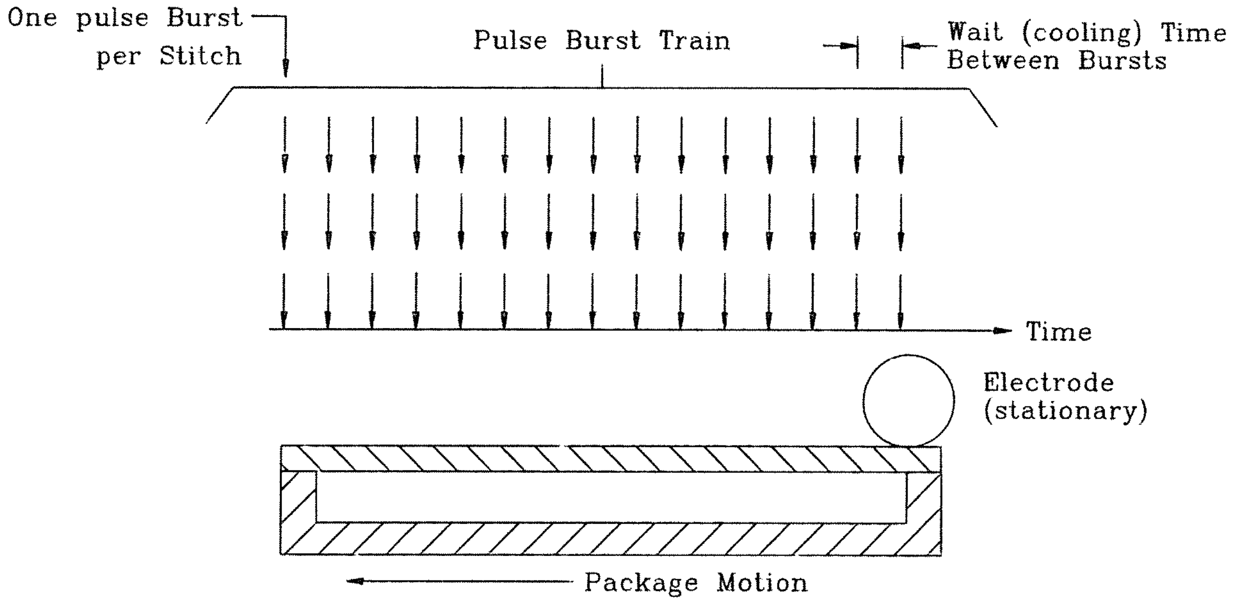
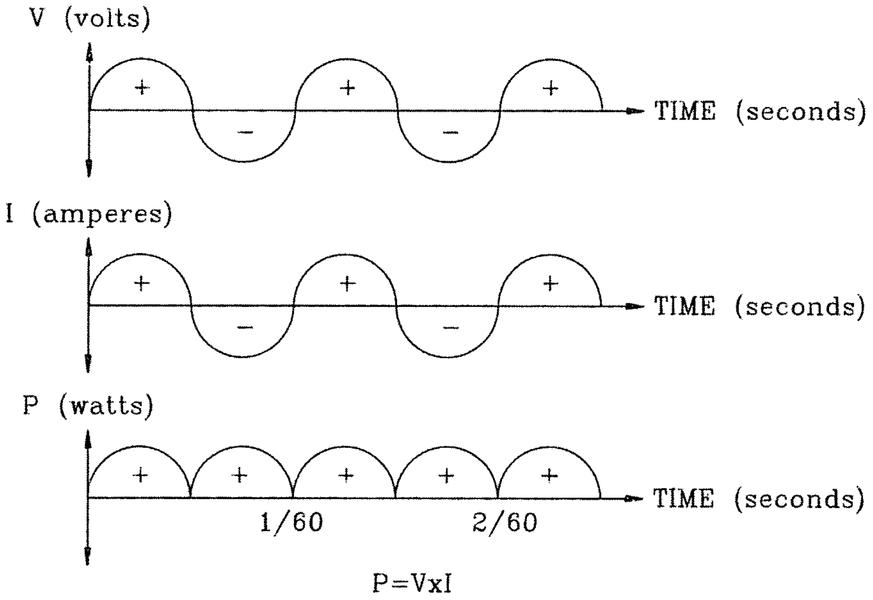


Figure 7
Hermetic Software



Note: There is no motion while a power burst is on; no pulse smearing.

Figure 8
"Cool" Software



P=VxI

Figure 9
Voltage-Current-Power in AC

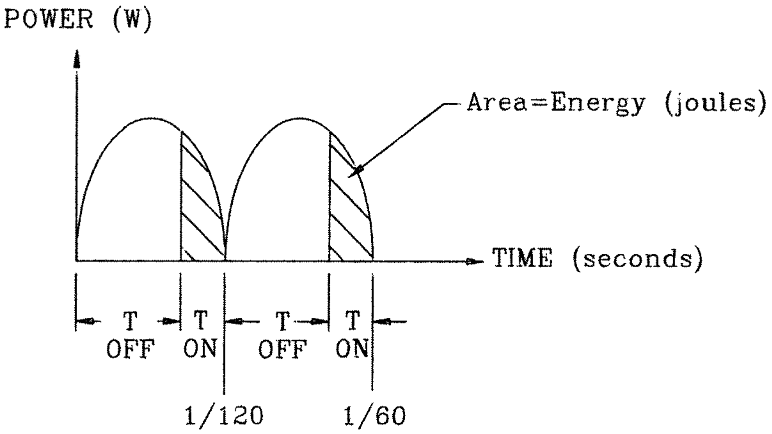


Figure 10
Phase Control of Energy (heat)

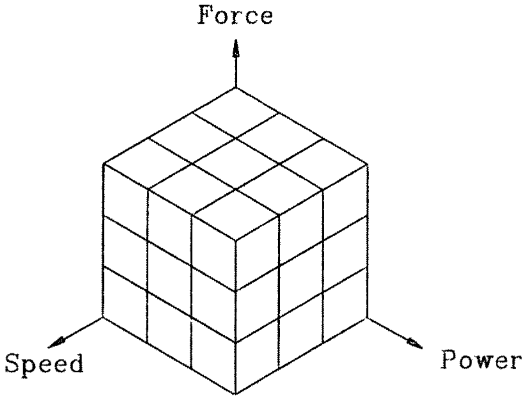


Figure 11
Power-Speed-Force Space

		ELECTRODE FORCE (NEWTONS)								
		30			20			10		
		SPEED %			SPEED %			SPEED %		
		90	70	50	90	70	50	90	70	50
POWER %	30	$1X10^{-7}$	$6X10^{-8}$	GROSS	$2X10^{-7}$	$5X10^{-8}$	$1X10^{-7}$	GROSS	$9X10^{-7}$	GROSS
	40	$1X10^{-4}$	$5X10^{-8}$	$1X10^{-7}$	$6X10^{-8}$	$6X10^{-8}$	$6X10^{-9}$	$7X10^{-8}$	$5X10^{-8}$	$8X10^{-8}$
	50	$1X10^{-3}$	$8X10^{-8}$	$2X10^{-4}$	$1X10^{-7}$	$1X10^{-7}$	$1X10^{-7}$	$1X10^{-7}$	$9X10^{-8}$	GROSS

Part No. XXX ; Electrode Angle YY° ; Overtravel .ZZZ"

Software: Hermetic

Quantity of Good Parts:

1) POWER:
   - 30% – 4
   - 40% – $\boxed{8}$
   - 50% – 6
2) SPEED:
   - 50% – 5
   - 70% – $\boxed{8}$
   - 90% – 5
3) FORCE:
   - 10N – 5
   - 20N – $\boxed{8}$
   - 30N – 5

Preliminary DEcision:

Normal Manufact. 24 Merit Points — POWER 40%, SPEED 70%, FORCE 20N

Best Hermeticity 21 Merit Points — POWER 40%, SPEED 50%, FORCE 20N

Figure 12
Schedule Developing Chart
Using Leak Rate as Criteria
(1x10 –7 secs.)