DUKANE

GUIDE TO ULTRASONIC PLASTICS ASSEMBLY

Intelligent Assembly Solutions

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Dukane ISO

ISO CERTIFICATION

Dukane chose to become ISO 9001:2008 certified in order to demonstrate to our customers our continuing commitment to being a quality vendor. By passing its audit, Dukane can assure you that we have in place a well–defined and systematic approach to quality design, manufacturing, delivery and service. This certificate reinforces Dukane's status as a quality vendor of technology and products.

To achieve ISO 9001:2008 certification, you must prove to one of the quality system registrar groups that you meet three requirements:

1. Leadership
2. Involvement
3. Quality in Line Organizations and Quality System Infrastructure.

The ISO 9001:2008 standard establishes a minimum requirement for these requirements and starts transitioning the company from a traditional inspection–oriented quality system to one based on partnership for continuous improvement. This concept is key in that Dukane no longer focuses on inspection, but on individual processes.

Dukane's quality management system is based on the following three objectives:

1. Customer oriented quality. The aim is to improve customer satisfaction.
2. Quality is determined by people. The aim is to improve the internal organization and cooperation between staff members.
3. Quality is a continuous improvement. The aim is to continuously improve the internal organization and the competitive position.

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ISO 9001:2008
CERTIFIED
Dukane products are manufactured in ISO registered facilities.

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DUKANE

INTRODUCTION

Company Profile

The success of any business is integrally tied to its ability to satisfy customers. DukaneCorporation has grown and expanded considerably since the company's founding in 1922, but has never lost sight of this fundamental tenet of business.

Headquartered in the Chicago suburb of St. Charles, Illinois, Dukane displays a unique commitment to continually improving its operations and its offerings to customers. The company's Total Quality Management process, an operating philosophy that all Dukane employees follow, provides a framework for improving internal operations as well as relationships with customers.

By focusing on customer needs and making a commitment to technology and development, Dukane's diverse and talented workforce continuously strives to bring the best products to the industrial, commercial, government, and institutional markets. All employees share a common goal of delivering the reliable, innovative, and cost-effective solutions that customers need. As an example, Dukane's Intelligent Assembly Solutions Division has significantly improved the quality and efficiency of industrial plastics welding techniques through computerized control of process variables. Dukane Ultrasonics' use of evolving pneumatic and servo technologies has given customers the flexibility to program equipment settings for improved product consistency and shorter, more productive manufacturing cycles.

For ninety years, Dukane has stood for quality, innovation, and dependability. Thank you for choosing Dukane. We appreciate your business and support, and look forward to serving your needs.

Chapter 1

ULTRASONIC BASICS

PROCESS DEFINITION

Ultrasonic plastics assembly is the joining or reforming of ther-moplastics through the use of heat generated from high frequency mechanical motion. It is accomplished by converting electrical energy into high frequency mechanical motion (vibrations) that creates frictional heat at the joint area. The vibrations, when applied to a part under pressure/ force, create frictional heat at the interface and cause the plastic in the joint area to melt, creating a molecular bond between the plastic components.

Most people are familiar with what happens when a metal object is repeatedly struck with a hammer. If the impact is hard enough and occurs often enough, the metal object begins to get warm. If this beating action continues, the metal can become surprisingly hot. The metal object gets hot because its molecules are moving, or vibrating, at a rate that causes an increase in temperature.

According to the basic laws of physics, the true definition of heat is “the energy associated with the random motions or vibrations of molecules.” Theoretically, only at absolute zero (calculated to be -273^{0}C and probably impossible to achieve) does molecular motion cease. So, in practice, the molecules of any substance are constantly vibrating. The amount of molecular vibration in a sub-stance determines its temperature. The more its molecules vibrate, the “hotter” a substance is. In the example above, the impact of the hammer causes the molecular vibration in the metal to increase and accounts for the rise in temperature. By focusing high frequency sound vibrations to a specific area of a thermoplastic, the material’s molecules are “shaken up” and the temperature increases until the material melts and either bonds to the adjoining part (welding) or takes the shape of the tool (reforming).

Since ultrasonic assembly is a heat-related process, some of the principles relative to heat welding and forming are the same. The primary difference is in how the heat is introduced to the desired location. With ultrasonics, the tool transmits high frequency sound vibrations which must travel through the material and focus at the desired melt location, causing heat to develop in the material itself.

HOW ULTRASONIC ASSEMBLY IS DONE

Ultrasonic assembly is accomplished by converting high frequency electrical energy into high frequency mechanical motion. That me-chanical motion, along with applied force, creates frictional heat at the plastic components’ mating surfaces (joint area) so the plastic material will melt and form a molecular bond between the parts. Standard 50 or 60 Hertz AC line voltage is supplied to the generator (power supply) and converted to 15,000 or 30,000 Hertz (i.e., 15 kHz or 30 kHz) AC electrical energy. This high frequency electri-cal energy is connected to a piezoelectric transducer (converter), which changes the electrical energy into mechanical vibrations. These vibrations, when applied to a part under force, will create frictional heat and cause the plastic to melt at the joint area. As the plastic cools, a homogeneous molecular bond is formed between the components.

ULTRASONIC WELDING

Ultrasonic welding is the most common application of ultrasonic assembly. In welding, the horn is brought into contact with one of the workpieces, pressure is applied and vibrating ultrasonic energy travels through the material, generating frictional heat at the joint area between the two parts. The plastic material melts and flows between the two part surfaces. When the vibrations stop, the plastic solidifies and the two workpieces are bonded together. **Figure 1-1** shows the ultrasonic welding process in more detail.

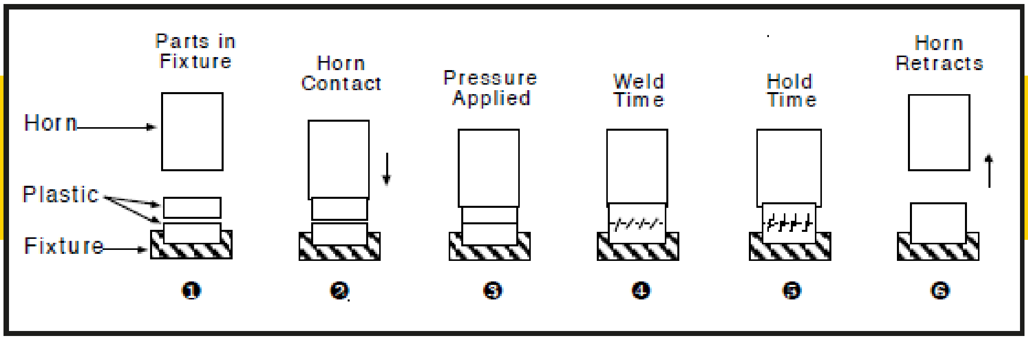

Figure 1-1 Ultrasonic Welding

1. The two thermoplastic parts to be joined are placed together, one on top of the other, on a supportive surface called a fixture.
2. A titanium or plated aluminum component called a horn is brought into contact with the upper plastic part.
3. A controlled pressure is applied to the horn, clamping the two plastic parts together against the fixture.
4. The horn is vibrated vertically 15,000 (15 kHz) or 30,000 (30kHz) times per second, at distances measured in thousandths of an inch (microns), for a predetermined amount of time called weld time. Through careful part design, this vibratory mechanical energy is directed to limited points of contact between the two parts.

   The mechanical vibrations are transmitted through the thermoplastic materials to the joint interface to create frictional heat. When the temperature at the joint interface reaches the melting point, plastic melts and flows, and the vibration is stopped. This allows the melted plastic to begin cooling.
5. The clamping force is maintained for a predetermined amount of time to allow the parts to fuse as the melted plastic cools and solidifies. This is known as hold time. (Note: Improved joint strength and hermeticity may be achieved by applying a higher force during the hold time.
6. Once the melted plastic has solidified, the clamping force is removed and the horn is retracted. The two plastic parts are now joined as if molded together and are removed from the fixture as one part.

ADVANTAGES OF ULTRASONIC ASSEMBLY

There are many advantages to using ultrasonic assembly. It is a fast, clean, efficient, and repeatable process that produces strong, integral bonds while consuming very little energy. No solvents, adhesives, me-chanical fasteners or external heat are required. Finished assemblies are strong and clean. Difficult materials can be assembled ultrasonically. Part assemblies are cycled quickly because the energy transferred to the joint and released as heat occurs very rapidly and is confined to the immediate joint area. The rapid dissipation of heat makes this process considerably faster than other methods of assembly.

An ultrasonic assembly system's tooling and/or application can be quickly changed offering flexibility and versatility not found in many other assembly processes. In addition, the relatively low-cost investment in ultrasonic equipment vs. its high reliability, long life, and consistent, repeatable performance, makes ultrasonic welding the preferred method of assembly. Ultrasonic assembly is widely accepted and is used in the automotive, medical, electrical and electronic, communications, appliances, consumer products, toys, and textile and packaging industries. It is an economical process that can significantly increase production and lower assembly costs.

SYSTEM COMPONENTS AND FUNCTIONS

The basic ultrasonic assembly system consists mainly of four major components:

- Generator (power supply)
- Transducer (converter)
- Booster
- Horn (acoustic tool)

A press to house the transducer-booster-horn stack and a fixture to hold mating parts are also needed to complete the ultrasonic plastics assembly system, but these components will be discussed later.

The **generator** changes standard electrical power (120 – 240 volts, 50/60 Hz) into electrical energy at the frequency at which the system is designed to operate. Although several different operating frequen-cies are in use throughout the world, the most common frequencies used in manufacturing production are 15, 20, 30, and 40 kilohertz (kHz). For the sake of simplicity, most of the information provided in this manual will pertain to 20 kHz, unless otherwise noted.

The high frequency electrical energy produced by the generator is sent through a cable to the **transducer**, which changes the elec-trical energy into vertical, low amplitude mechanical motion, or vibrations.

These vibrations are then transmitted to a booster, which is used to increase or

decrease the amplitude of the vibrations. Amplitude is defined as:

> *The peak-to-peak excursion, or travel distance, of the vibration of a booster or horn at its workface.*

The amount of amplitude required depends on the material, the type of application, and the work that needs to be performed. It is often necessary to change the amplitude of the vibration going into the horn so that the desired result is appropriate for the specific application. The booster increases or decreases amplitude to make this possible. The amount of the increase or decrease in amplitude is expressed as a ratio known as gain. Gain is defined as:

> *The ratio of output amplitude to input amplitude of a booster or horn.*
> *(Gain is the result of the ratio of a booster or horn's input and output masses.)*

Therefore, a 2 to 1 booster attached to a transducer doubles the amplitude of the vibrations leaving the workface of the booster. A 3:1 booster triples the amplitude of the vibrations. A 0.5:1 booster decreases the amplitude of the vibrations by one-half.

The vibrations are then transmitted to a **horn** of the proper size and shape to best deliver the vibrational energy to the workpiece. Depending on its shape, the horn may further increase the amplitude of the vibrations.

Figure 1-2 above shows the function of each basic system component and how the vibrational energy is created and increased.

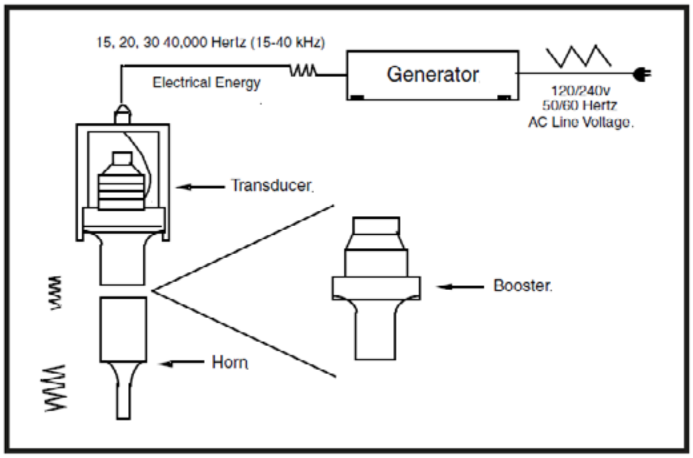

Figure 1-2 Basic System Components and Their Functions

See the Amplitude Reference Table on the next page >>

Thermoplastic 20kHz Amplitude Reference

Amorphous Resins	Microns	Thousandths	Semi-Crystalline Resins	Microns	Thousandths
ABS (Cycolac)	30-70	1.2-2.8	Acetal (Delrin, Celcon)	75-125	3.0-5.0
ABS/Polycarbonate (Cycoloy, Pulse)	50-125	2.0-5.0	Liquid Crystal Polymers (Xydar)	60-125	2.4-5.0
Phenylene-Oxide (Noryl)	50-90	2.0-3.6	Polyamide (Nylon, Zytel)	60-125	2.4-5.0
Polycarbonate (Lexan)	50-100	2.0-4.0	Polyester PBT (Celanex, Valox)	60-125	2.4-5.0
Polycarbonate/Polyester (Xenoy Macroblend)	50-100	2.0-4.0	Polyester PET (Rynite)	60-125	2.4-5.0
Polyetherimide (Ultem)	60-125	2.4-5.0	Polyetherether Ketone (PEEK)	60-125	2.4-5.0
Polymethyl Methacrylate (Acrylic, Plexiglass)	40-70	1.6-2.8	Polyethylene P/E	70-125	2.8-5.0
Polystyrene	60-65	1.2-2.6	Polymethylpentene (TPX)	70-125	2.8-5.0
Polysulfone (Udel)	65-100	2.6-4.0	Polyphenylene Ether/Oxide (Prevex)	60-125	2.4-5.0
Polyvinylchloride (Rigid PVC)	40-75	1.6-3.0	Polyphenylene Sulfide PPS (Ryton)	80-125	3.2-5.0
SAN/NAS	30-65	1.2-2.6	Polypropylene P/P	70-125	2.8-5.0
Styrene Block Copolymers (K-Resin)	40-90	1.6-3.6			

Applications	Microns	Thousandths
Welding	30-125	1.2-5.0
Staking	75-125	3.0-5.0
Swaging	75-125	3.0-5.0
Inserting	25-65	1.0-2.6
Spot Welding	50-125	2.0-5.0
Degating	75-125	3.0-5.0

Trademarked names appear in parentheses.

NOTE: The information in this table is for reference only. Contact your material supplier or Dukane regarding your individual project.

Table 1-1 Amplitude Reference Table

More Information: Refer to Dukane's *Stack Amplitude and Thermoplastic Reference Guide*, a document that can be downloaded: *https://documents.dukane.com/DesignGuides/ThermoGuide.pdf*

Summary - The generator provides high frequency electrical energy to the transducer, which changes it to ultrasonic vibrational energy. The booster alters the amplitude of the vibrational energy between the transducer and the horn so that it is appropriate for the specific application. The horn is designed to apply the vibrational energy to the part being assembled.

TECHNIQUES FOR

APPLYING THE ENERGY

TO THE WORK

It is necessary to have some type of ultrasonic plastics assembly system to apply the vibrational energy to workpieces. The type of system needed is determined by the application itself. A hand-held convert-a-probe system (See **Figure 1-3**.) may be used where it is more practical to bring the ultrasonic energy to the workpiece. For more critical applications where precise control and repeatability are required, a press system would probably be recommended. (See **Figure 1-4**.) When the production rate calls for speeds that exceed what could be done on a standard press, a rotary index parts handling system can be used to increase productivity and meet production demands. (See **Figure 1-5**.) For very high speed assembly, an ultrasonic unit housing the stack assembly (i.e., the transducer - horn assembly) can be used in conjunction with automated machinery. (See **Figure 1-6**.) In situations where the size of a press system becomes difficult to deal with (usually involving dedicated, custom installations), thrusters (sometimes called actuators) may be used. Thrusters (See **Figure 1-7**.) offer the control of a press in a smaller package more suited to custom mounting.

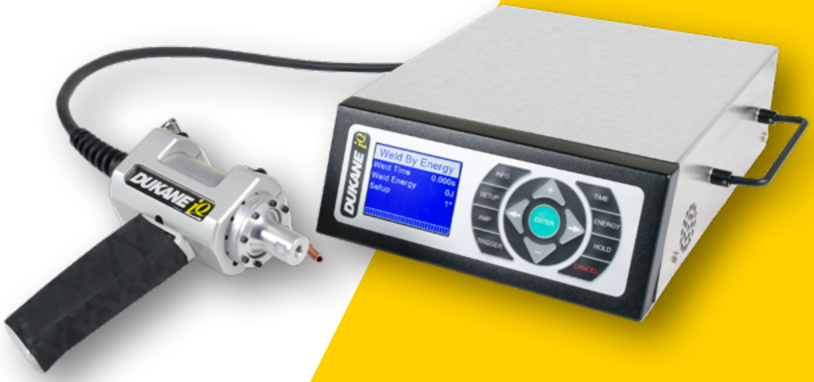

Figure 1-3 Hand-held Convert-a-Probe Syst

Figure 1- 4 Press System

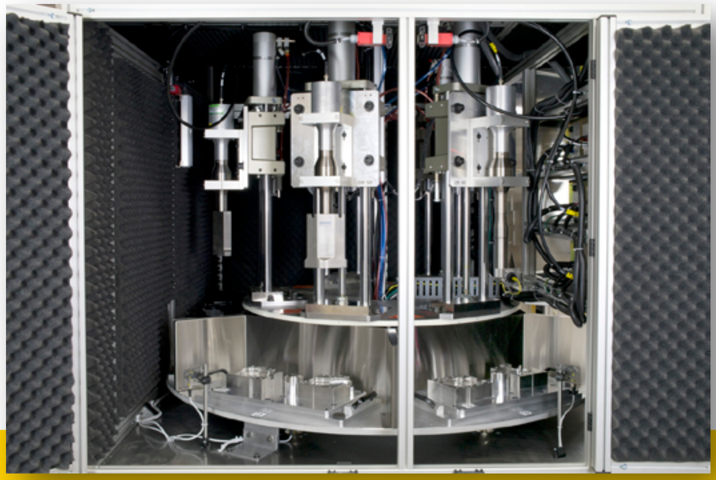

Figure 1- 5 Rotary Index Parts Handling System

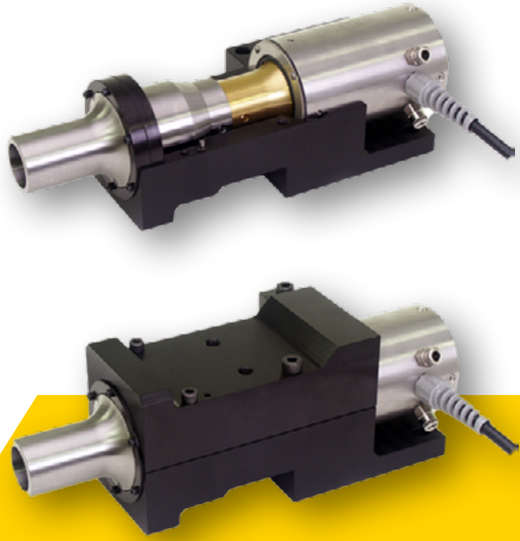

Figure 1- 6 Custom Stack Mount.

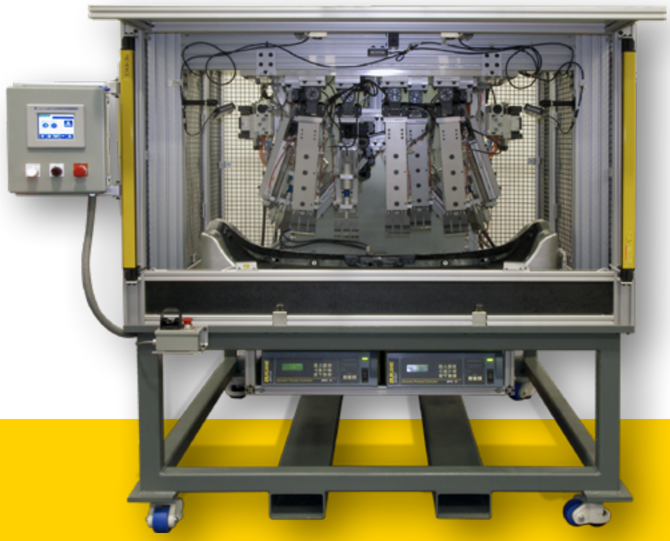

Figure 1- 7 Thruster Units

PLASTICS

Chapter 2

PLASTIC MATERIALS

Plastics are synthetic or manufactured materials formed by combining two or more of the six chemical elements that go into the building of a polymer. A **polymer**, or resin, is a chemical compound or mixture of compounds formed by polymerization, which is a chemical reaction where two or more molecules combine to form larger molecules of a substance. There are two basic types of polymers: **thermosets** and **thermoplastics**.

Thermosets undergo irreversible molecular change during processing and become permanently insoluable and infusible. They cannot be melted or reformed in their final state. Thermosets are hard, brittle substances that simply degrade when subjected to intense heat. Therefore, thermosets are not suitable for ultrasonic assembly.

Thermoplastics, however, soften upon heating and harden when cooled, and can be reheated and remolded. Since the ultrasonic assembly process depends on the ability of the material to be softened, thermoplastics are ideally suited for ultrasonic assembly.

Polymer molecules are long chains, five hundred to ten thousand times greater in length than in thickness. The molecular structure of a thermoplastic determines its physical properties, and its melting and welding characteristics. A thermoplastics' molecular structure is classified as either **amorphous** or **semi-crystalline**. The molecules of an amorphous thermoplastic are arranged randomly. In contrast, semi-crystalline molecules have a very orderly and repeated structure. In the molded part, the molecules are aligned and interlocked with each other. **Figures 2-1** and **2-2** illustrate the molecular structure of amorphous and semi-crystalline materials.

Major amorphous thermoplastics include ABS, styrene, acrylic, PVC, and polycarbonate. Major semi-crystalline thermoplastics include acetal, nylon (polyamide), polyester, polyethylene, polypropylene, and fluoropolymers.

Amorphous materials do not have a defined melting point. When heated, they gradually soften as they pass from a rigid state, through a glass transition, into a rubbery state, followed by a liquid flow in a true molten state. Solidification is likewise gradual.

Figure 2-1 Amorphous Molecular Structure

Figure 2-2 Semi-Crystalline Molecular Structure

Semi-crystalline materials have a sharp melting point. A high level of heat energy is required to break down the crystalline structure before melting can occur. The semi-crystalline material remains solid until it reaches the melt temperature, when it immediately becomes liquid. The molecules are, at that point, able to flow. Solidification occurs just as rapidly due to the sudden recrystal-lization of the molecules. **Figure 2-3** illustrates the differences in molten states for amorphous and semi-crystalline materials.

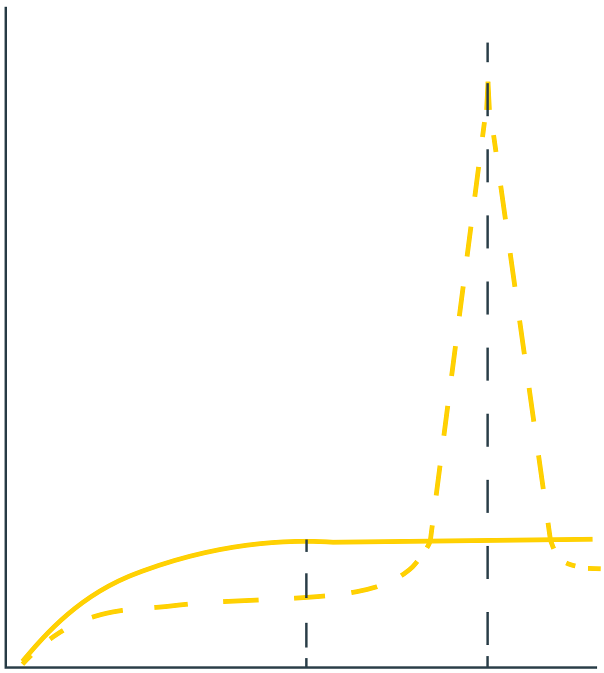

Figure 2-3 Molten States for Amorphous and Semi-crystalline Materials

The higher amount of energy required to melt semi-crystalline materials is one reason they are more difficult to weld than amor-phous materials. Another reason has to do with the ability of a plastic to transmit mechanical energy in the form of vibrations. In semi-crystalline materials, their orderly molecular structure absorbs vibrational energy, making it much more difficult to transmit mo-tion from the horn contact point, through the plastic, to the joint interface of the parts being welded. With amorphous materials, the random arrangement of molecules allows the vibrational energy to pass through them easily, with little attenuation.

COMPATIBILITY OF MATERIALS

To bond two thermoplastic parts, it is necessary that the materials be chemically compatible. Otherwise, *even though both materials may melt together, there will be no molecular bond*. A good example would be trying to weld polyethylene to polypropylene. Both of these semi-crystalline materials have a similar appearance and many common physical properties. However, they are *not* chemically compatible, and are therefore unable to be welded to each other.

CAUTION

Even when welding thermo-plastics with the same chemical properties, you should use material from the:

- same supplier, and
- same resin grade to avoid unpredictable welding results.

Like thermoplastics (i.e., materials with the same chemical proper-ties) will weld to themselves. For example, one ABS part will weld to another ABS part. Dissimilar thermoplastics *may* be compatible only if their melt temperatures are within 40°F (6°C) and they are of like molecular structure. For example, it is likely that an ABS part could be welded to an acrylic part because their chemical properties are compatible. Generally speaking, only similar amorphous polymers have an excellent probabilty of being welded to each other. The chemical properties of any semi-crystalline material make each one only compatible with itself. See **Figures 2-5** and **2-6** for typical material compatibility.

When the materials to be welded are compatible, several other factors may affect the weldability of the parts. These factors include hygroscopicity, mold release agents, lubricants, plasticizers, fillers, flame retardants, regrind, pigments, and resin grades. Each of these factors is discussed below.

HYGROSCOPICITY

Hygroscopicity is the tendency of a material to absorb moisture. Resins such as polyamide (nylon), polycarbonate, polycarbonate/polyester alloy (xenoy), and polysulfone are hygroscopic (i.e., they absorb and retain moisture from the air).

Hygroscopicity negatively affects weldability. If moist parts are welded, the water trapped within the material itself evaporates and boils off when the temperature reaches the boiling point. This cre-ates a foamy condition at the joint interface that makes it difficult to achieve a hermetic seal and gives the assembled parts a poor cosmetic appearance. The strength of the bond is also compromised. **Figure 2-4** indicates that moisture results in longer weld cycles.

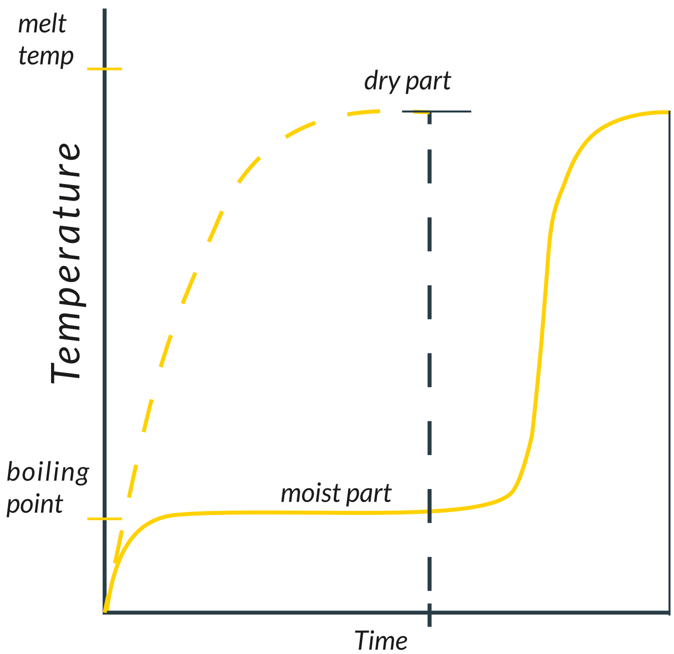

Figure 2-4 Effect of Hygro- scopicity on Weld Times

Hygroscopic parts should be welded immediately after molding. If this is not possible and the parts must be stored prior to assembly, they should be sealed in polyethylene bags with a desiccant. Parts stored without some form of protection against moisture may have to be dried before welding.

Mold release agents are usually sprayed directly on the mold cavity surface and are used to make parts eject from the mold cavity more readily by reducing friction between the part and the cavity walls. Unfortunately, mold release agent on the molded parts reduces surface friction in the joint interface between the parts when they are being welded. Since the ultrasonic assembly process depends on surface friction, the use of mold release agents can be detrimental to weldability. Furthermore, the chemical contamination of the resin by the release agent can inhibit the formation of the desired bond. Some agents can be removed from parts with a preassembly cleaning operation using suitable solvents. If a release agent must be used, paintable/printable grades that permit painting and silk screening are preferred because they interfere least with ultrasonic assembly and often require no preassembly cleaning. Use of zinc stearate, aluminum stearate, fluorocarbons, and silicones should be avoided if possible.

LUBRICANTS

Lubricants such as waxes, zinc stearate, stearic acid, aluminum stearate, and fatty esters are added to resins to improve flow characteristics and enhance resin processability. Since internal lubricants cannot be removed and will reduce the coefficient of friction at the interfaces of the parts to be welded, they can defeat the entire ultrasonic process.

PLASTICIZERS

Plasticizers are used to increase the flexibility and softness of a material and have a tendency to migrate or return to the joint of a welded part after a period of time, resulting in a weakened bond or joint. The FDA-approved plasticizers are preferred to the metallic plasticizers, but experimentation is advised prior to production.

FILLERS

Fillers such as glass fiber, talc, carbon fiber, and calcium carbonate are added to resins to alter their physical properties. For instance, a glass filler might be added to a resin to improve its dimensional stability or material strength. Common mineral fillers, such as glass or talc, can actually enhance the weldability of thermoplastics because they improve the resin's ability to transmit vibrational energy, particularly for semi-crystalline materials. A glass con-tent of 10% – 20% can substantially improve the transmission properties of a resin.

It must be recognized, however, that a direct ratio between the addition of fillers and the improvement of weldability exists only within a prescribed quantitative range. When levels exceed 10% – 20%, other problems can arise. For example, even though the filler content of a finished part may be 30% by weight, the actual content level molded into the joint could be much higher. The ac-cumulation of filler at the joint interface (known as **agglomeration** or **filler enrichment**) can become so severe that there may not be enough resin in the joint interface to form an acceptable weld. If the amount of filler *in the joint* exceeds 40%, then there is more *unweldable* material there than weldable material. This means that weldability becomes more difficult to achieve consistently and overall assembly strength suffers.

Filler contents above 20% can cause excessive horn and fixture wear that may require special tooling. Because of the presence of particles at the resin surface, heat-treated steel or carbide-faced titanium horns may need to be used. Higher powered ultrasonic equipment may also be required to create sufficient heat at the joint.

FLAME RETARDANTS

Flame retardants are used to alter the combustible properties of plastics. Retardants such as antimony, boron, halogens, nitrogen, and phosphorous are added to resins to keep temperatures below a combustion level or to prevent a chemical reaction between the resin and oxygen or other combustion-aiding gases. Flame retardants can directly affect thermoplastic weldability by reducing the strength of the finished joint. High-power equipment, operating at higher than normal amplitudes, is often required so that the parts can be “overwelded” to achieve adequate strength.

REGRIND

Regrind is the term given to plastic material that has been recycled or reprocessed and added to the original resin. Ultrasonic assembly is one of the few processing methods that permits regrinding of parts, since no foreign substance is introduced into the resin. Providing that the percentage of regrind is not excessive, and the plastic has not been degraded or contaminated, few problems should arise. However, for best results, it is advisable to keep the regrind percent-age as low as possible.

COLORANTS

Liquid or dry colorants, or pigments, have very little effect on weldability unless the percentage of colorant to resin is exceedingly high. White and black parts often require more pigments than other colors and may cause some problems. Different colors of the same part may result in different setup parameters. Experimentation is recommended prior to full production.

RESIN GRADE

The resin grade can have a significant effect on an application’s weldability. Resin grade is important because different grades of the same material can have very different melt temperatures, resulting in poor welds or apparent incompatibility. Whenever possible, materials of the same grade should be used in the ultra-sonic assembly process.

Ultrasonic Weldability Compatibility Chart for Thermoplastics

	ABS (Cycolac)	ABS/Polycarbonate (Cycoloy)	Acetal (Delrin, Celcon)	Acrylic (Plexiglass, Perspex)	Acrylic Multipolymer (XT)	Liquid Crystal Polymers (Xydar)	Nylon (Zytel)	Phenylene Oxide (Noryl)	Polycarbonate (Lexan)	Polycarbonate/Polyester (Xenoy)	Polyester PBT (Celanex, Valox)	Polyester PET (Rynite)	Polyetherether Ketone (PEEK)	Polyetherimide (Ultem)	Polyethylene P/E	Polyphenylene Ether/ Oxide (Prevex)	Polyphenylene Sulfide PPS (Ryton)	Polypropylene P/P	Polystyrene	Polysulfone (Udel)	Polyvinylchloride (Rigid PVC)	SAN/NAS	Styrene Block Copolymers (K-Resin)
ABS (Cycolac)	■	■		■																			●
ABS/Polycarbonate (Cycoloy)	■	■		●					●											●			
Acetal (Delrin, Celcon)			■																				
Acrylic (Plexiglass, Perspex)		●		■	●					●												●	●
Acrylic Multipolymer (XT)		●		●	■																	●	
Liquid Crystal Polymers (Xydar)						■																	
Nylon (Zytel)							■																
Phenylene Oxide (Noryl)								■	●													●	
Polycarbonate (Lexan)		■		■					■	●													
Polycarbonate/Polyester (Xenoy)		●		●					●	■	●												
Polyester PBT (Celanex, Valox)										●	■												
Polyester PET (Rynite)												■											
Polyetherether Ketone (PEEK)													■										
Polyetherimide (Ultem)														■									
Polyethylene P/E															■								
Polyphenylene Ether/Oxide (Prevex)																■							
Polyphenylene Sulfide PPS (Ryton)																	■						
Polypropylene P/P																		■					
Polystyrene	●							■											■			●	●
Polysulfone (Udel)																				■			
Polyvinylchloride (Rigid PVC)																					■		
SAN/NAS	●			●	●			●											●			■	
Styrene Block Copolymers (K-Resin)	●			●															●				■

■ Good compatibility

● Compatible at times based on material compositionon

Figure 2-5 Materials Compatibility Chart

Ultrasonic Weldability Assembly Characteristics

	ABS (Cycolac)	ABS/Polycarbonate (Cycoloy)	Acetal (Delrin, Celcon)	Acrylic (Plexiglass, Perspex)	Acrylic Multipolymer (XT)	Liquid Crystal Polymers (Xydar)	Nylon (Zytel)	Phenylene Oxide (Noryl)
ABS (Cycolac)		A	G	G	G	G	G	G
ABS/Polycarbonate (Cycoloy)	H	A	G	G	G	G	G	G
Acetal (Delrin, Celcon)		C	F	G	F	P	G	F
Acrylic (Plexiglass, Perspex)	H	A	G	G	G	G	G	G
Acrylic Multipolymer (XT)		A	G	G	G	G	G	G
Liquid Crystal Polymers (Xydar)		C	F	G	F	F	G	G
Nylon (Zytel)	H	C	G	G	F	F	G	G
Phenylene Oxide (Noryl)		A	G	G	G	G	G	G
Polycarbonate (Lexan)	H	A	G	G	G	G	G	G
Polycarbonate/Polyester (Xenoy)	H	A/C	G	G	G	G	G	G
Polyester PBT (Celanex, Valox)		C	G	G	F	F	G	G
Polyester PET (Rynite)		C	G	G	F	F	F	G
Polyetherether Ketone (PEEK)		C	F	G	F	G	G	F
Polyetherimide (Ultem)		C	G	G	F	F	G	G
Polyethylene P/E		C	G	F	G	G	P	G
Polyphenylene Ether/Oxide (Prevex)		C	G	G	G	G	G	G
Polyphenylene Sulfide PPS (Ryton)		C	G	G	F	F	G	F
Polypropylene P/P		C	G	G	G	G	F	G
Polystyrene		A	G	G	G	G	G	G
Polysulfone (Udel)	H	A	G	G	G	G	G	G
Polyvinylchloride (Rigid PVC)		A	G	G	G	G	G	G
SAN/NAS		A	G	G	G	G	G	G
Styrene Block Copolymers (K-Resin)		A	G	G	G	G	G	G

H = Hygroscopic – Material should be dry before assembling

RESIN TYPE
A = Amorphous
C = Semi-Crystalline

ASSEMBLY RATINGS
G = Good F = Fair P = Poor

This chart is intended to be used as a guide only. Other variables such as part configuration, joint design, amplitude requirements, and individual resin grade and composition may affect results.

Figure 2-6 Assembly Characteristics

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JOINT AND PART DESIGN

Chapter 3

BASIC REQUIREMENTS

The joint design of the mating pieces is critical in achieving optimum assembly results. A particular part's joint design depends upon factors such as type of plastic, part geometry, and the requirements of the weld. There are many different joint designs, each with its own advantages. Some of these designs are discussed later in this section.

There are three basic requirements in joint design:

- A uniform contact area
- A small initial contact area
- A means of alignment

A **uniform contact area** means that the mating surfaces should be in intimate contact around the entire joint. The joint should also be in one plane, if possible. A **small initial contact area** should be established between the mating halves. Doing so means less energy, and therefore less time, is required to start and complete the "meltdown" between the mating parts. A **means of alignment** is recommended so the mating halves do not misalign during the welding operation. Alignment pins and sockets, channels, and tongues are often molded into parts to serve as ways to align them. **Note:** it is best not to use the horn and/or fixture to provide part alignment.

The need for the basic requirements for any joint design can be demonstrated using a flat butt joint. Only the high points will weld on a flat butt joint, resulting in erratic, inconsistent welds. Extending the weld time to increase the melt simply enlarges the original weld points and causes excessive flash outside of the joint, as shown in **Figure 3-1**.

Bringing one of the surfaces to a point produces welds with good appearance, but little strength. When good strength is achieved, excessive flash ruins the appearance of the weld. **Figure 3-2.** illustrates the problems encountered with pointed wall parts

THE ENERGY DIRECTOR

The **energy director** was developed to provide a specific volume of material to be melted so that good bond strength could be achieved without excessive flash. It is the joint design that is generally recommended for amorphous polymers.

An energy director is a triangular-shaped bead molded into the part interface. It typically runs around the entire joint perimeter. When ultrasonic energy is transmitted through the part under pressure and over time, the energy concentrates

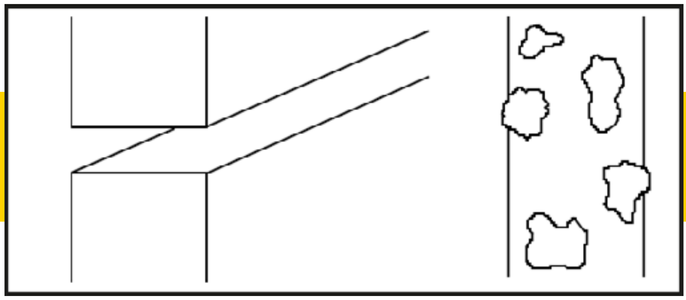


Figure 3-1 Flat Butt Joint Welds

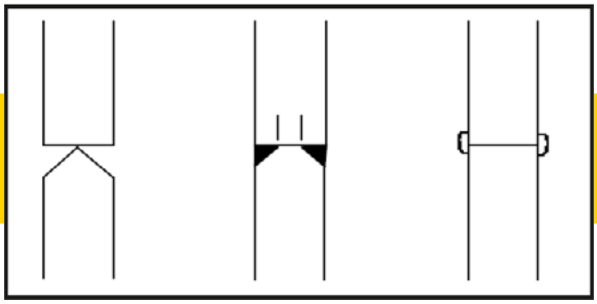


Figure 3-2 Problems with Pointed Wall Parts

at the apex of the energy director (i.e., where the apex of the trianglular-shaped bead contacts the other mating surface) resulting in a rapid buildup of heat that causes the the bead to melt. The molten material flows across the joint interface forming a molecular bond with the mating surface.

In terms of the three basic requirements of a joint design, the energy director meets two: it provides a uniform and a small initial contact area. The energy director itself does not provide a means of alignment, nor does it provide a means to control material flash. These requirements must be incorporated into the part design.

The basic energy director design for an amorphous resin is a right triangle with the 90 degree angle at the apex and the base angles each at 45 degrees. (See **Figure 3-3**.) This makes the height one-half the base width. The size of this energy director can range from 0.005” (0.127mm) to 0.030” (0.762mm) high and from 0.010” (0.254mm) to 0.060” (1.53mm) wide. For polycarbonate, acrylics, and semi-crystalline resins, the energy director is an equilateral triangle, with all three angles being 60 degrees. (See **Figure 3-4**.) This makes the height 0.866 times the base width. The base width can range from 0.010” (0.254mm) to 0.050” (1.27mm).

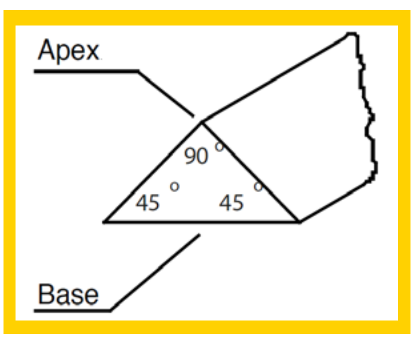


Figure 3-3 Energy Director for Amorphous Resins

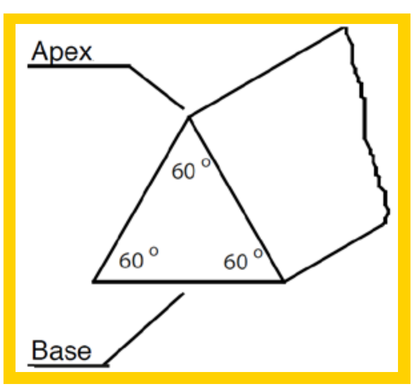


Figure 3-4 Energy Director for Semi-crystalline ..... Resins

The most common and basic joint design is the butt joint with an energy director as shown in **Figure 3-5**. The width of the energy director’s base is between 20% and 25% of the thickness of the wall (i.e., B = W/4 to W/5). When the wall is thick enough to produce an energy director larger than the maximum size, two smaller parallel energy directors should be used. The height at the apex of the energy director is either half the base or 0.866 times the base, depending on the material. This design produces a weld across the entire wall section with a small amount of flash normally visible at the finished joint. As stated before, the parts should be designed to include a means of alignment. If this is not possible, the fixture can be designed to provide the locating features necessary to keep the parts aligned with respect to each other. Typically, hermetic seals are easier to achieve with amorphous rather than semi-crystalline materials. If a hermetic seal is required, it is important that the mating surfaces be as close to being perfectly flat and/or parallel to each other as possible.

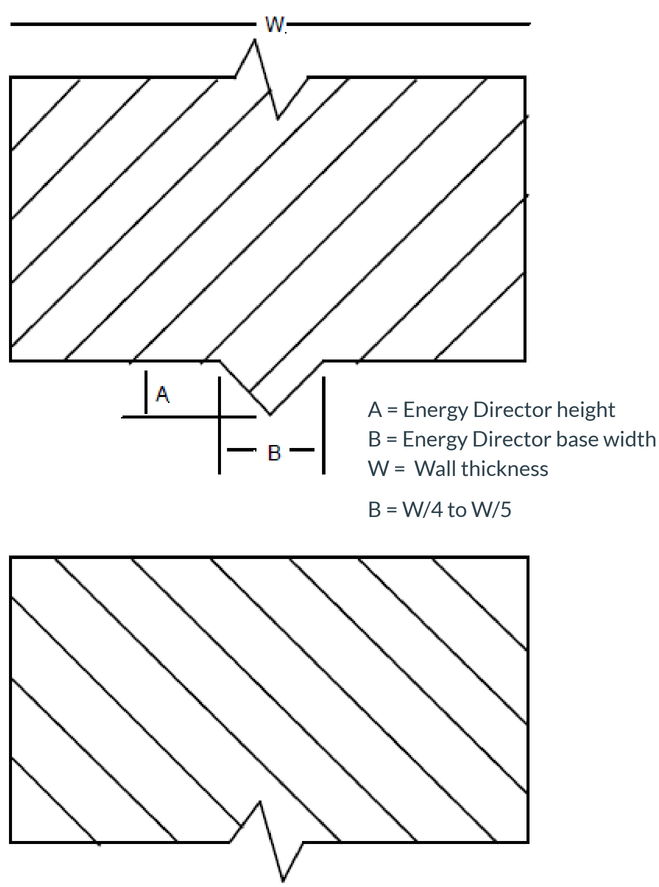


Figure 3-5 Butt Joint with an Energy Director

The butt joint with an energy director is well-suited for amorphous resins because they are capable of molten flow and gradual solidification. However, it is not the best design for semi-crystalline resins. With semi-crysalline resins, the material displaced from the energy director usually solidifies before it can flow across the joint to form a seal. This causes a reduction in overall strength and makes hermetic seals difficult to achieve. However, sometimes there are certain limitations imposed by the design or size of the part that make it necessary to use an energy director on semi-crystalline parts. In situations where an energy director must be used with a semi-crystalline resin, it should be larger and have a steeper angle to give it a sharper point (apex). This enables it to partially imbed in the mating surface during the early stages of the weld, thereby reducing the amount of premature solidification and degradation caused by exposure to the air. The larger, sharper design improves the strength and increases the chances of obtaining a hermetic seal. Experimentation has shown that the larger, sharper energy director design is also superior when working with polycarbonate and acrylics, even though both materials are classified as amorphous materials.

The graphs depicted in **Figure 3-6** shows the impact of welding a butt joint with an energy director (i.e., a small initial contact) area versus welding a plain butt joint, which is, in effect, no joint at all. As can be seen, the butt joint with an energy director is brought up to melt temperature in a much shorter period of time than the plain butt joint. The butt joint with an energy director also provides a much stronger weld.

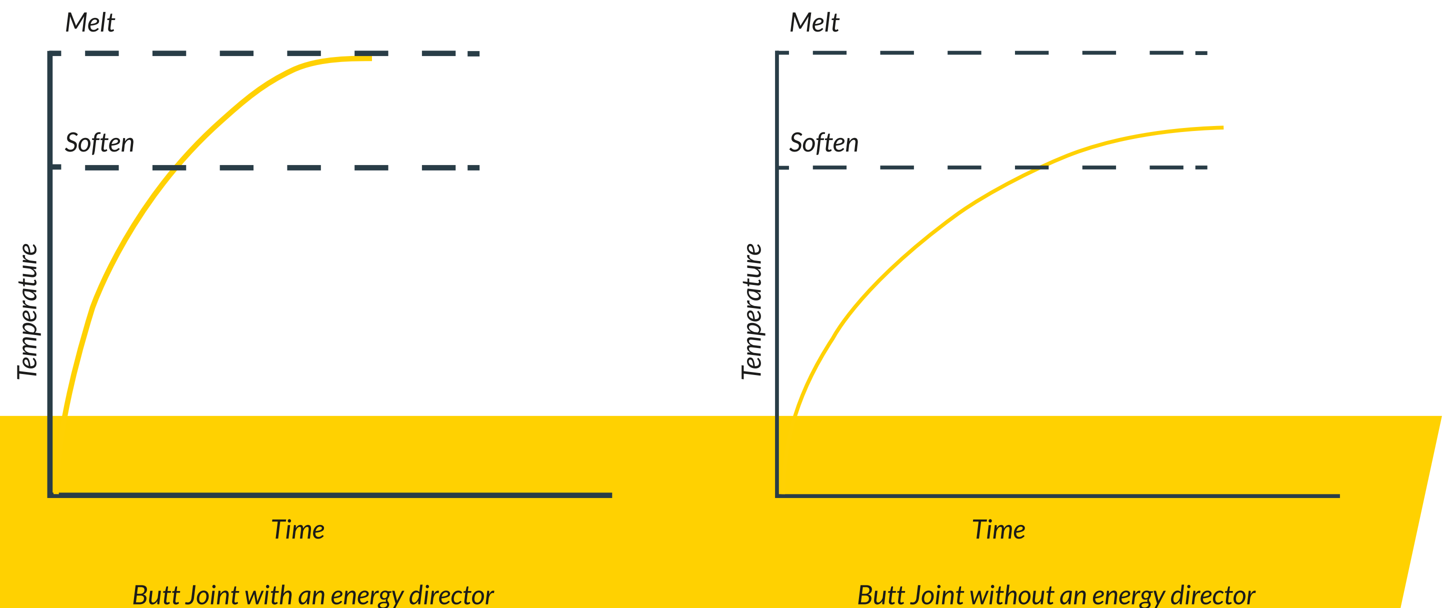


Figure 3-6 Time and Temperature Graphs for Butt Joints

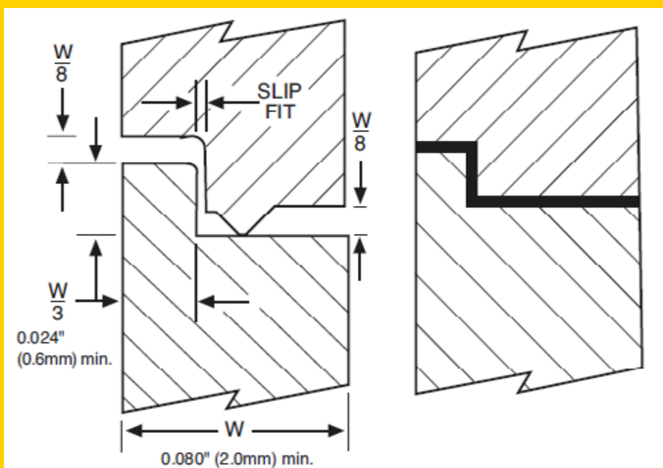
THE STEP JOINT

One variation of the energy director joint design is the step joint. Like the energy director, it meets two of the basic requirements of joint design: it provides a uniform contact area and a small initial contact area. A step joint also provides a means of alignment. **Figure 3-7** on the next page shows a step joint.

As only part of the wall in a step joint is involved in the welding, its strength is less than that of a butt joint with an energy director. The recommended minimum wall thickness is 0.080" (2.03mm) to 0.090" (2.29mm).

A step joint may be used when cosmetic appearance of the assembly is important. Use of a step joint can eliminate flash on the exterior and produce a strong joint, since material from the energy director will typically flow into the clearance gap between the tongue and the step. The energy director is dimensionally identical to the one used on the butt joint. The height and width of the tongue are each one-third of the wall thickness (T = W/3). The width of the groove is 0.002"– 0.004" (0.05mm–0.10mm) greater than that of the tongue to ensure that no interference occurs (G = T +

0.002” to 0.004”). The depth of the groove should be 0.005” to 0.010” (0.13mm–0.25mm) greater than the height of the tongue, leaving a slight gap between the finished parts (D = T + 0.005” to 0.010”). This is done for cosmetic purposes so that it will not be obvious if the surfaces are not perfectly flat or the parts are not perfectly parallel.



Before weld *After weld*

Figure 3-7 Step Joint

THE TONGUE-AND-GROOVE JOINT

The tongue-and-groove joint is another variation of the energy director. Like the step joint, it provides the three requirements of a joint design (a uniform contact area, a small initial contact area, and a means of alignment). It also prevents internal and external flash, since there are flash traps on both sides of the interface. **Figure 3-8** shows a tongue-and-groove joint.

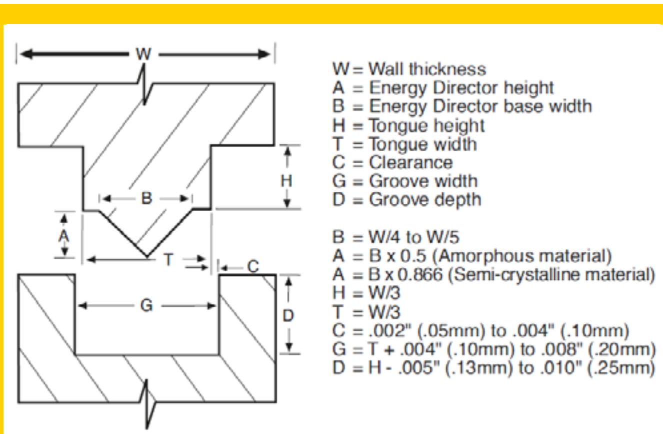


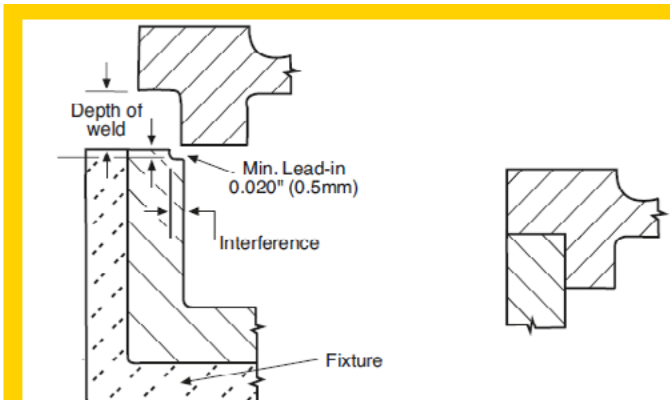
Figure 3-8 Tongue-and-Groove Joint

The tongue-and-groove joint is primarily used for applications where self-location and flash prevention are important. It is an excellent joint design with applications calling for low pressure hermetic seals. The main disadvantage of the tongue-and-groove joint is that less weld strength is possible because less area is affected by the joint. The minimum wall thickness recommended for use with the tongue-and-groove joint is 0.120” (3.05mm) to 0.125” (3.12mm).

Again, the energy director is dimensionally identical to the one used in the butt joint. The height and width of the tongue are both one-third the the thickness of the wall. Clearance should be maintained on each side of the tongue to avoid interference and provide space for the molten material. Therefore, the groove should be 0.004” (0.10mm) to 0.008” (0.20mm) wider than the tongue. The depth of the groove should be 0.005” (0.13mm) to 0.010” (0.25mm) less than the height of the tongue. As with the step joint, a slight gap designed into the finished part assembly proves to be advantageous for cosmetic reasons.

THE SHEAR JOINT

The shear joint is used when a strong hermetic seal is needed, especially with semi-crystalline resins. **Figure 3-9** depicts a shear joint. A shear joint requires that a certain amount of interference be designed into the part.



Before weld *After weld*

Figure 3-9 Share Joint

Welding is accomplished by first melting the contacting surfaces. As the melting parts telescope together, they continue to melt with a controlled interference along the vertical walls. A flash trap, which is an area used to contain the material displaced from the weld, may be used.

The smearing action of the two melt surfaces at the weld interface eliminates leaks and voids, as well as exposure to air, premature solidification, and possible oxidative degradation. The smearing action produces a strong structural weld.

Note in **Figure 3-9** the depiction of a fixture. Rigid sidewall support is very important with shear joint welding to prevent part deflection during welding. The walls of the fixtured part need to be supported up to the joint interface by the fixture, which should closely conform to the shape of the part. In addition, to make it easier to remove the part from the fixture, the fixture itself should be split so that it can be opened and closed.

A shear joint meets the three requirements of joint design. The lead-in provides a means of alignment and self-location of the parts to be welded. Properly designed and molded parts ensure a uniform contact area. The small initial contact area between the parts occurs at the base of the lead-in.

Table 3-1 *presents general guidelines recommended for interference and part tolerance in relation to maximum part dimension when designing shear joints based on part size. Semi-crystalline parts using a shear joint should be no larger than 3-1/2" (88.9mm) in diameter. Amorphous materials may be larger.*

Part Diameter	Interface per side (Range)	Part Diameter (Tolerance)
Less than 0.75" (18mm)	0.008" to 0.012" (0.2 to 0.3mm)	± 0.001" (± 0.025mm)
0.75" to 1.50" (18 to 35mm)	0.012" to 0.016" (0.3 to 0.4mm)	± 0.002" (± 0.050mm)
Greater than 1.5" (35mm or greater)	0.016" to 0.020" (0.4 to 0.5mm)	± 0.003" (± 0.075mm)

Minimum wall thickness = 0.075" (1.8 mm)

Tsble 3-1 Shear Joint Interference Guidelines

PART DESIGN

There are considerations other than the basic design of the joint that must be taken into account in the design of the parts themselves.

NEAR FIELD VS. FAR FIELD WELDING

In many applications, the location of the joint in regard to the area of horn contact can be critical, since the ultrasonic energy must travel through the material to reach the desired area of melt. Near field and far field welding refer to the distance ultrasonic energy is transmitted from the point of horn contact to the joint interface. When the distance between the horn and joint interface is 1/4" (6mm) or less, it is *considered near field*. When the distance is greater than 1/4" (6mm), the weld is considered far field. **Figure 3-10** illustrates near and far field welding.

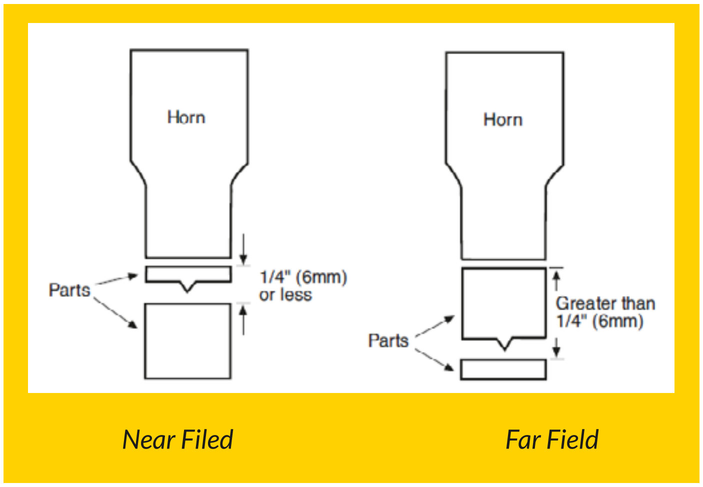


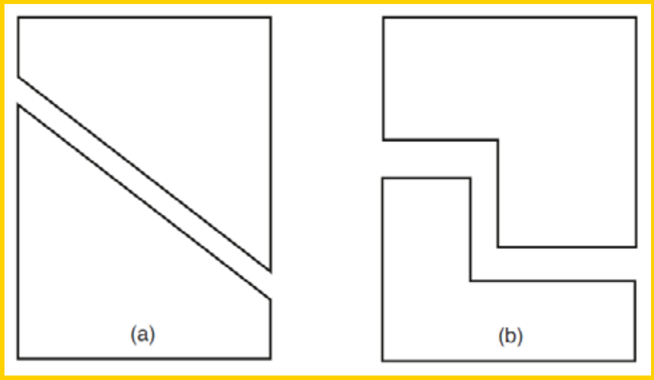
Figure 3-10 Near Field and Far Field Welding

Whenever possible, it is always best to weld near field. Far field welding requires higher than normal amplitudes, longer weld times, and higher air pressures to achieve a comparable near field weld. Generally speaking, far field welding is advised only for amorphous resins, which transmit energy better than semi-crystalline resins.

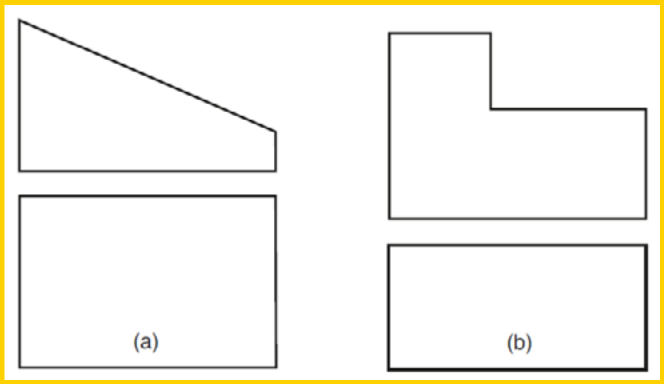
PARALLEL CONTACT

To achieve an optimum weld, it is important that the joint interface be on a single plane, parallel to the horn contact surface, so that the ultrasonic energy travels the same distance through the plastic part to get to the joint. For the same reasons, the surface that the horn contacts should also be on a single plane parallel to the joint. The near field and far field examples shown in **Figure 3-10** meet these criteria. The examples in the next two figures do not. While the joint interface in **Figure 3-11a** is on a single plane, it is not parallel to the surface that the horn contacts. Energy would have to travel farther through the material on the right side of the part than on the left, resulting in uneven heating and melting. Welded assemblies would be very inconsistent, producing either weak structural bonds or overwelded bonds. In **Figure 3-11b**, the joint interface is parallel with the horn contact surface, but it is on two planes, not a single plane.

In **Figure 3-12a**, the horn contact surface would be on a single plane, but would not be parallel to the joint interface. The horn contact surface in **Figure 3-12b** would be parallel with the joint interface, but it would be on two planes, not a single plane.



Joint interface should be on a single plane parallel to the surface of horn contact



Joint interface should be on a single plane parallel to the surface of horn contact

Figure 3-11a Joint on a Single Plane, NOT Parallel to Horn Contact Surface

Figure 3-11b Joint Parallel to Horn Contact Surface but NOT on a Single Plane

Figure 3-12a Horn Contact Surface on a Single Plane, but NOT Parallel to Joint Interface

Figure 3-12b Horn Contact Surface Parallel to Joint Interface but NOT on a Single Plane

OTHER PART DESIGN CONSIDERATIONS

SHARP CORNERS

Sharp corners localize stress. When subjected to ultrasonic vibratory energy, plastic parts with sharp corners may fracture or melt in those high stress areas. To reduce stress fracturing, we recommend a generous radius on all corners and edges.

HOLES OR VOIDS

Energy does not travel well around holes, voids, angles, or bends. Depending on material type, hole size, angle, etc., little or no welding will be achieved directly beneath these areas. Eliminate all sharp angles, bends, and holes, where possible.

APPENDAGES

Appendages, tabs, or other protrusions molded onto plastic parts also focus stress when subjected to vibratory energy and have a tendency to degate (i.e., fall off). Ways to minimize this include adding a generous radius to the areas where the appendages join the main part, applying a light force to the appendage(s) to dampen the flexure, making appendages thicker, or using 40 kHz equipment, if possible

DIAPHRAGMMING

Thin sectioned, flat, circular parts may flex or "diaphragm" when subjected to ultrasonic energy. Typically, when the horn contacts such a part, it may experience an "oil-canning" effect, bending up and down. Heat from the intense flexing of the material may cause it to melt or burn a hole through it. Diaphragmming will often occur in the center of a part or at the gate area. Making those sections thicker may prevent diaphragmming.

OTHER ASSEMBLY TECHNIQUES

Chapter 4

STAKING

Staking is the process of melting and reforming a stud to mechanically lock a material in place. It provides an alternative to welding when:

- The two parts to be joined are made of dissimilar materials that cannot be welded (e.g., metal and plastic), or
- Simple mechanical retention of one part relative to another is adequate (i.e., molecular bonding is not necessary)

The advantages of staking include short cycle time, tight assemblies with no tendencies to spring back, the ability to perform multiple stakes with one horn, good process control and repeatability, simplicity of design, and elimination of consumables, such as screws or adhesives.

The most common staking application attaches metal to plastic. A hole in a metal part is designed to receive a stud or boss, which is molded into the plastic part. (Note: the stud should be designed with a generous radius at its base to prevent fracturing.) A vibrating horn with a contoured tip contacts the stud and creates localized, frictional heat. As the stud melts, light pressure from the horn reforms the head of the stud to the configuration of the horn tip. When the horn stops vibrating, the plastic material solidifies and the metal and plastic parts are fastened together.

General guidelines for staking applications include:

- Use of a high amplitude horn with a small contact area to localize heat and increase the rapidity of the melt
- Light initial contact force with controlled horn descent velocity to concentrate the ultrasonic energy at the limited horn/stud contact area
- Pre-triggering the ultrasonic energy to create an out-of-phase relationship, preventing horn/stud coupling
- A slow actuator down speed to prevent stud fracture while allowing plastic material to flow into the horn cavity
- A heavier hold force during the hold time to give the stud optimum strength to retain the attached material

The integrity of an ultrasonically staked assembly depends upon the geometric relationship between the stud and horn cavity, and the ultrasonic parameters used when forming the stud. Proper stake design produces optimum stud strength and appearance with minimum flash. The design depends on the application and physical size of the stud or studs being staked. The principle of staking, however, is always the same — the initial contact area between horn and stud must be kept to a minimum, concentrating the energy to produce a rapid, yet controlled melt.

THE ENERGY DIRECTOR

The **energy director** was developed to provide a specific volume of material to be melted so that good bond strength could be achieved without excessive flash. It is the joint design that is generally recommended for amorphous polymers.

An energy director is a triangular-shaped bead molded into the part interface. It typically runs around the entire joint perimeter. When ultrasonic energy is transmitted through the part under pressure and over time, the energy concentrates

THE STANDARD ROSETTE PROFILE STAKE

Of the five basic staking designs, the standard rosette profile stake satisfies most requirements. **Figure 4-1** shows how a standard rosette profile stake is formed.

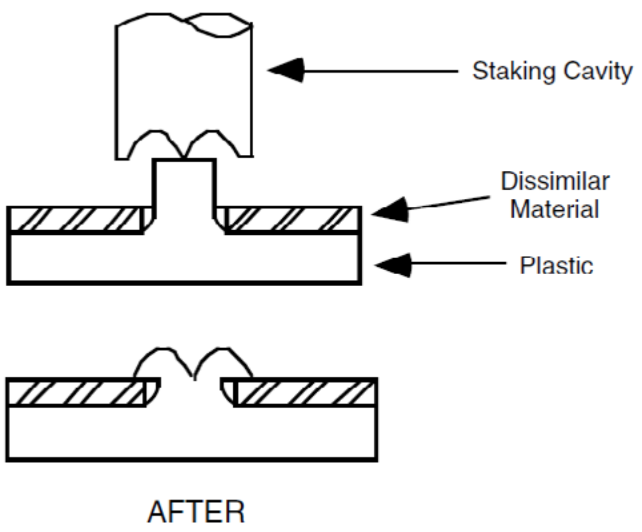


Figure 4-1 Standard Rosette Profile Stake

It produces a head having twice the diameter of the original stud. It is designed to stake studs with flat heads and is recommended for studs 1/16" (1.6mm) O.D. (outside diameter) or larger. This stake is ideal for staking non-abrasive rigid and non-rigid thermoplastics.

THE DOME STAKE

The dome stake is typically used for studs of less than 1/16" (1.6mm) O.D. or with multiple studs where horn alignment can be a problem. It is also recommended for glass-filled resins where horn wear is possible, because the horn cavity can be redressed more easily than standard staking cavities using the inverted staking cone. **Figure 4-2** shows how a dome stake looks.

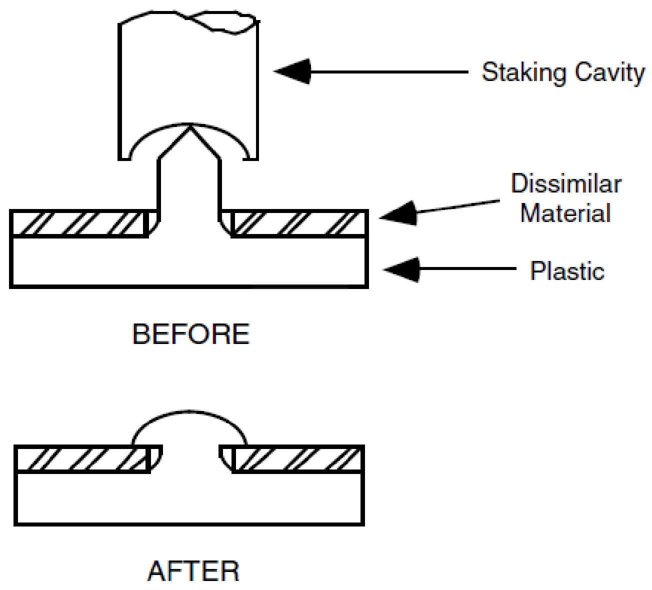


Figure 4-2 Dome Stake

The studend of a dome stake should be pointed to provide a small initial contact area prior to staking. Horn and stud alignment is not as critical as with the standard rosette profile stake.

THE HOLLOW STAKE

The hollow stake is used on studs that are 5/32" (4mm) or larger in diameter. A hollow stake is shown in **Figure 4-3**. The hollow stake offers advantages in molding because it prevents surface sinks and internal voids. Hollow staking reduces ultrasonic cycle time because less material is being melted and reformed.

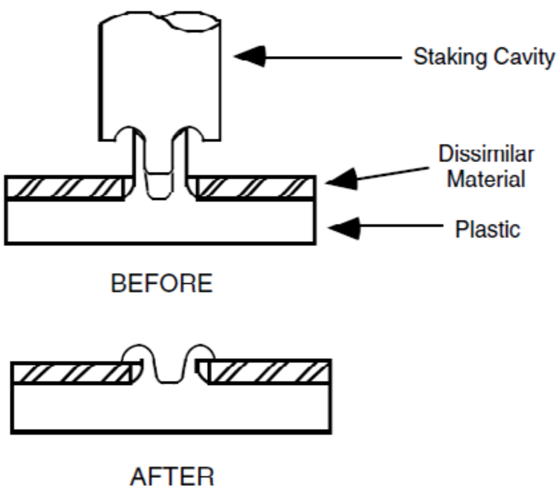


Figure 4-3 Hollow Stake

Staking a hollow stud produces a large, strong head. In applications where disassembly for repair is a primary requirement, the formed stud head can be removed for access, and reassembly can be accomplished by driving a self-tapping screw into the hole in the hollow stud.

THE KNURLED STAKE

The knurled stake is used for simplicity and a rapid assembly rate. Multiple stakes may be made without concern for precise alignment or stud diameter. The knurled stake may be used with all thermoplastics where appearance is not critical. Figure 4-4 depicts a knurled stake.

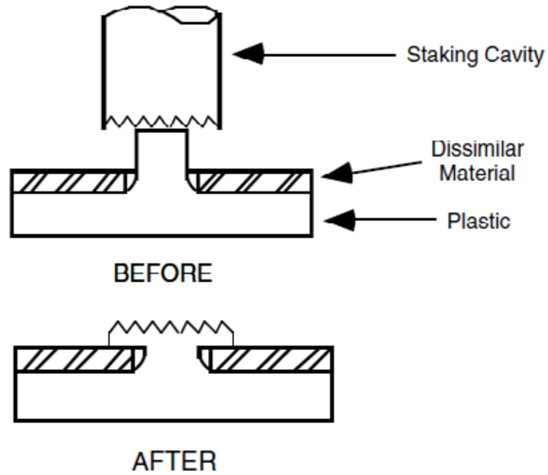


Figure 4-4 Hollow Stake

THE FLUSH STAKE

The flush stake is used when a raised stud head is not permitted above the surface of the attached part. The tapered stud design used for dome staking is recommended. The hole in the part to be attached is countersunk so that the volume of the melted stud fills that area, locking the attached part in place. **Figure 4-5** shows a flush stake.

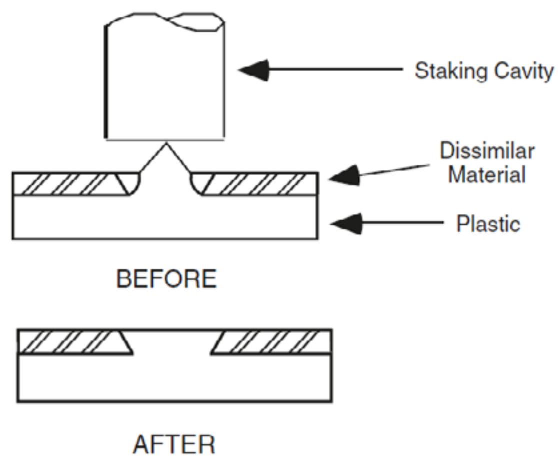


Figure 4-5 Flush Stake

STUD WELDING

An alternative to staking is ultrasonic stud welding. This process can be used to join plastic parts of similar material at single or multiple localized attachment points. Thus, the technique is useful in applications that do not require a continuous weld.

Stud welding can be used when resin selection, size, or part complexity prevent the use of other techniques. A variation of the shear joint is used in stud welding. Generally, a stud is driven into a hole, with welding occurring along the circumference of the stud.

INSERTION

Insertion is the assembly process of embedding a metal component in a thermoplastic part. A hole is pre-molded into the thermoplastic part slightly smaller than the O.D. of the insert it is to receive. As ultrasonic energy is applied to the insert, frictional heat is generated due to the insert vibrating against the plastic. The plastic melts, permitting the insert to be driven into place. The insert is surrounded by molten plastic, which flows around the knurls, flutes, and undercuts on the O.D. of the insert. Total process time is usually less than one second. **Figure 4-6** illustrates the insertion process.

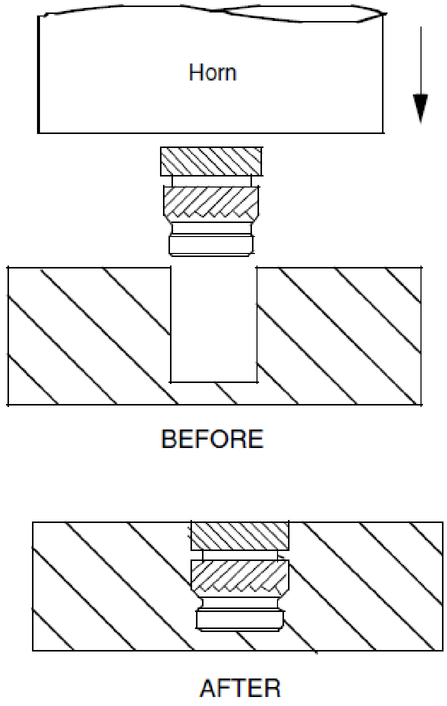


Figure 4-6 Insertion

Ultrasonic insertion combines the high-performance strength of a conventional molded-in insert with the advantages of post-molded installation. Advantages include: short cycle times, no induced stress in the plastic around the metal insert, elimination of possible mold damage and down time should inserts fall into the mold, and reduced molding cycle times. Insertion also allows multiple inserts to be driven simultaneously and is ideal for automated, high-production operations. Insertion is a very repeatable and controlled process.

General guidelines for insertion applications include:

- Low amplitude to reduce horn stress
- Medium to high pressure to prevent cold pressing the inserts
- Slow down speed to allow the thermoplastic to soften
- Pre-triggering the ultrasonic energy to prevent a stall condition
- Horn face should be 3-4 times the diameter of the insert when possible to prevent horn/insert coupling

Ultrasonic insertion can be performed in two ways:

1. The horn can contact the insert, driving it into the plastic part.

2. The horn can contact the plastic part, driving it over the insert.

The method used is determined by the particular requirements of an application. However, the advantages of having the horn contact the plastic and driving it over the insert are reduced horn wear and less noise during the assembly process. If the horn must contact the metal insert, it is advised that a hardened steel horn be used, due to the high wear of metal-to-metal, horn/insert contact. Horns made of titanium may also be used. Although titanium is not as wear-resistant as hardened steel, it has a higher tensile strength, which makes it capable of handling more stress.

Common applications for ultrasonic insertion include threaded bore inserts, eyeglass hinges, machine screws, threaded rods, decorative trims, electrical contacts, and terminal connectors.

SWAGING AND FORMING

Swaging is the process of capturing another component of an assembly by melting and reforming a ridge of plastic (usually the outside wall). It is a method of assembling two materials without creating a molecular bond. The material that is swaged is always thermoplastic. The material of part that is captured is typically a dissimilar material, such as glass. **Figure 4-7** on the next page shows an example of swaging. Forming is the process of physically changing the shape of a plastic part.

The advantages of using swaging include a tight finished assembly, fast cycle times, and the elimination of fasteners and/or adhesives. Both swaging and forming require special tooling and consideration of the properties of the materials involved.

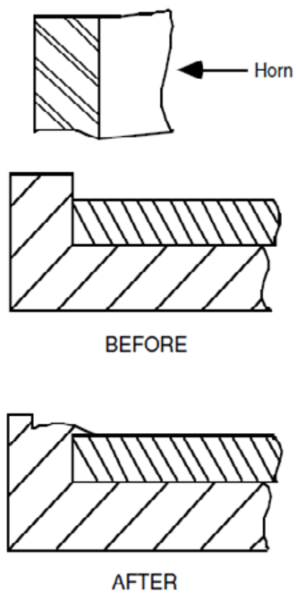


Figure 4-7 Swaging

In swaging, the horn face dictates how the plastic melts and flows, as well as the final swaged shape. The swage can be continuous or segmented.

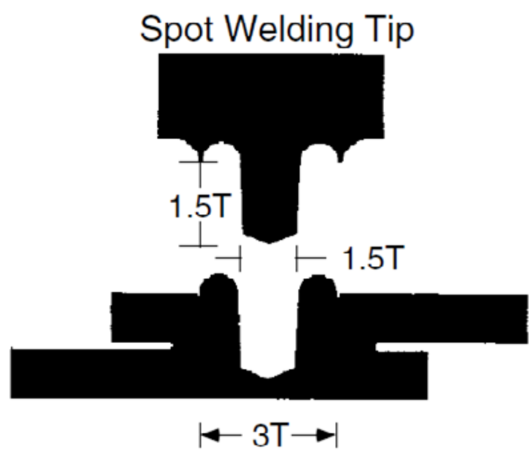
General guidelines for swaging applications include:

- High initial trigger pressure with controlled velocity to begin cold forming the plastic
- Pre-triggering of the ultrasonic energy so that the vibrating horn immediately begins melting the material on contact
- Using a heavier hold pressure to help overcome material memory

SPOT WELDING

Ultrasonic spot welding joins two like thermoplastic components at localized points with no pre-formed hole or energy director. It produces a strong weld and lends itself to large parts, sheets of extruded or cast thermoplastic, and parts with complicated geometry and/or hard-to-reach surfaces. Spot welding is often used on vacuum-formed parts, such as blister (clamshell) packaging. Most thermoplastics can be spot welded.

In spot welding, a specially designed spot welding tip melts through the top thermoplastic layer and part way into the second layer. The weld occurs at the interface between the two sheets. Figure 4-8 shows a cross-section of a spot weld and a spot welding tip.



T = Thickness of top layer of thermoplastic

Figure 4-8 Cross-Section of a Standard Spot Weld

The bottom layer of a spot welding joint has a smooth appearance. The top layer has a raised ring around the joint. It is a fast assembly process, requiring no extra fasteners, and generally, no special fixturing is needed.

The basic guidelines for spot welding include:

- Rigid support directly under the spot weld area to prevent marking
- Medium to high amplitude to ensure adequate material penetration
- Low pressure so that adequate melt can be made at the joint interface

At times, spot welding is accomplished using a hand-held transducer, called a convert-a-probe, such as the one shown previously in the *Ultrasonic Basics* section of this publication.

DEGATING

Degating is an ultrasonic assembly technique used in separating injection molded parts from their runner systems. By applying ultrasonic energy to the runner in an out-of-phase manner, the parts are melted off at the gate. Degating works best with rigid thermoplastics such as ABS, styrene, or acrylics.

The advantages that ultrasonic degating offers are speed of operation (typical cycle time is less than one second), low stress on parts, and a clean break at the part surface.

There are two major guidelines associated with degating:

- The gate area should be small (0.060" (1.5mm) long) and/or thin (0.015" (0.4mm) thick)
- Horn contact should be as close to the gate as possible

SCAN WELDING

Scan welding is the continuous, high-speed ultrasonic welding of flat parts that are conveyed beneath a stationary ultrasonic horn, or rotary horn and anvil. This process is suitable for rigid thermoplastic parts that have at least one flat surface for horn contact. Some fabric or film applications are also suitable for this process.

Both large and small thermoplastic parts may be scan welded. The joint designs that should be used for rigid thermoplastics are self-locating designs such as tongue and groove, step, and pin and socket.

BONDING AND SLITTING

Ultrasonic assembly techniques are used in several applications in the textile, apparel, and nonwoven industries. Two of the most common are ultrasonic bonding and ultrasonic slitting.

ULTRASONIC BONDING

Ultrasonic bonding assembles two or more layers of nonwoven materials by passing them between a vibrating horn and a rotary drum (often referred to as an anvil). Figure 4-9 illustrates ultrasonic bonding. The rotary drum is usually made out of steel and has a pattern of raised areas machined into it.

The high frequency mechanical motion of the vibrating horn and the compressive force between the horn and the rotary drum create frictional heat at the point where the horn contacts the material(s), bonding the material(s) together in the pattern of the rotary drum. Bonding takes place only at the horn/material contact points, which gives the bonded material(s) a high degree of softness, breathability, and absorption. These properties are especially critical for hospital gowns, sterile garments, diapers, and other applications used in medical industry and clean room environments.

Ultrasonic bonding uses much less energy than thermal bonding, which uses heated rotary drums to bond material(s) together. As with other ultrasonic assembly techniques, ultrasonic bonding requires no consumables, adhesives, or mechanical fasteners.

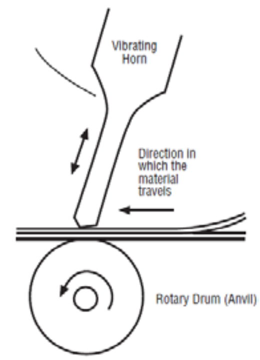


Figure 4-9 Ultrasonic Bonding

ULTRASONIC SLITTING

When a thermoplastic material is slit ultrasonically, its edges are also sealed. Sealing the edges of a woven fabric is beneficial because yarns are prevented from unravelling and the smooth, beveled edges prevent buildup of the roll material. Two or more layers of woven and/or nonwoven materials can be slit and melted together during ultrasonic slitting.

Speed of operation can be a significant advantage with ultrasonic slitting. The shape of the cutting wheel (anvil) determines the speed and width of the ultrasonic seal.

There are three methods of ultrasonic slitting/sealing: continuous, plunge, and traversing. The method used depends on the application requirements and the material manufacturing process(es) involved.

In the *continuous* method, the horn and anvil remain in a fixed location and the material is fed through the gap between them. Using the plunge method, the material remains in a fixed location and is periodically contacted by the horn. With the traversing method, the material remains in a fixed location and the horn moves over it.

Chapter 5

MAJOR COMPONENT DESIGN

GENERATORS

A generator takes standard alternating current (AC) electrical power (120/240 Vac, 50/60 Hz) and transforms it into electrical energy at the frequency at which a system is designed to operate. Dukane generators are available with output frequencies of 20 kHz (20,000 cycles per second), 40 kHz, 30 kHz, and 15 kHz and various output power levels up to 4,800 watts.

Ultrasonic generators employ a basic design, as shown in **Figure 5-1**. When power is supplied to the generator, high voltage is applied to the power amplifier. Transistors in the power amplifier are alternatively switched on and off at a rate of 20,000 cycles per second (for a 20 kHz system) or 40,000 cycles per second (for a 40 kHz system). This, in turn, sends a high-powered 20 kHz or 40 kHz signal to the transducer. When the transducer begins to vibrate, an electrical signal (i.e., feedback signal), in the form of a sine wave, is sent back to the power amplifier. This signal represents the actual resonant frequency of the load, which is the transducer-booster-horn stack assembly.

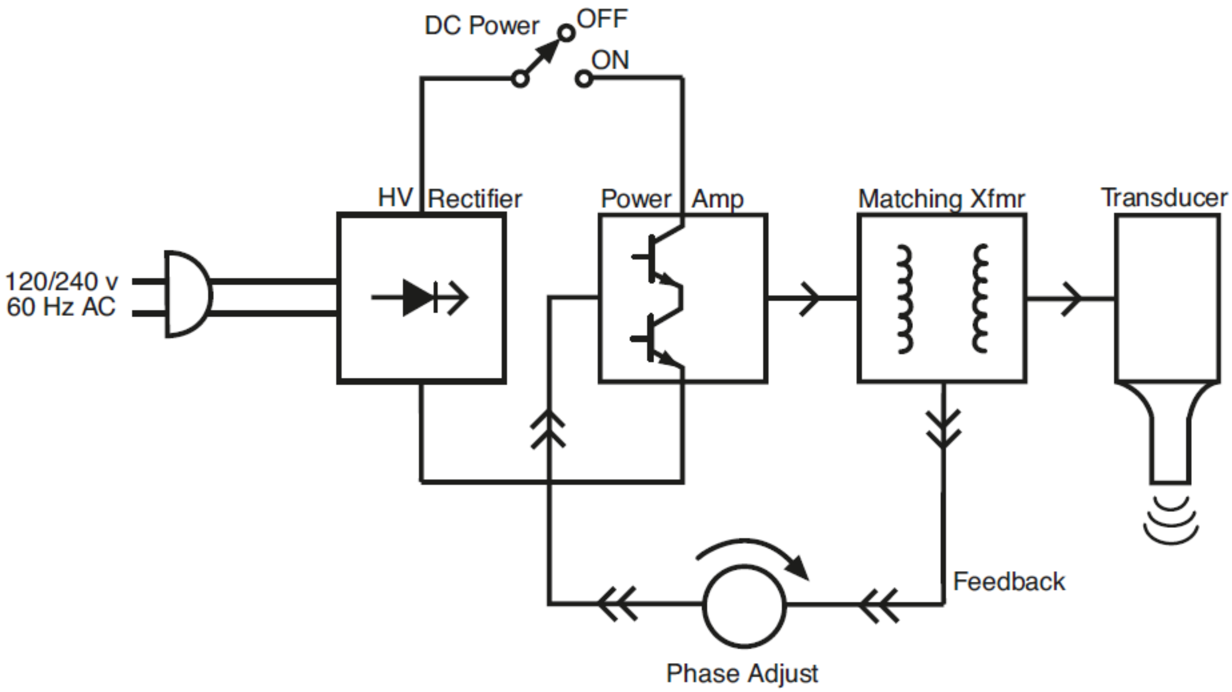


Figure 5-1 Conventional Generator Design

In early ultrasonic generator designs, it was necessary for an operator to adjust a tuning device (a "phase adjust" control) so that the frequency of the power amplifier matched the frequency of the load presented by the acoustic stack assembly. This matching of frequencies allowed the generator to be "in phase" with the transducer. It is important to note that at the instant these early generators were activated, there was no feedback signal, since the transducer was not yet vibrating. Very high levels of power could be drawn from the generator until the transducer was vibrating and the generator could be brought into phase with the transducer. These repeated, instantaneous high power draws put undue stress on system electrical components. The situation was even more critical because the transducer also had to excite the booster and horn. For applications that required large horns, which require more power to start, the repeated, power surges at start-up became potentially destructive to system mechanical and electrical components.

In an attempt to alleviate these start-up problems, a "soft-start" circuit was developed that applies half amplitude to the load during the start-up period. On most generators, the start-up time is between twenty-five and fifty milliseconds (25–50msec), as shown in **Figure 5-2**. After start-up, the circuit switches to full power and the transducer-booster-horn stack goes to full amplitude.

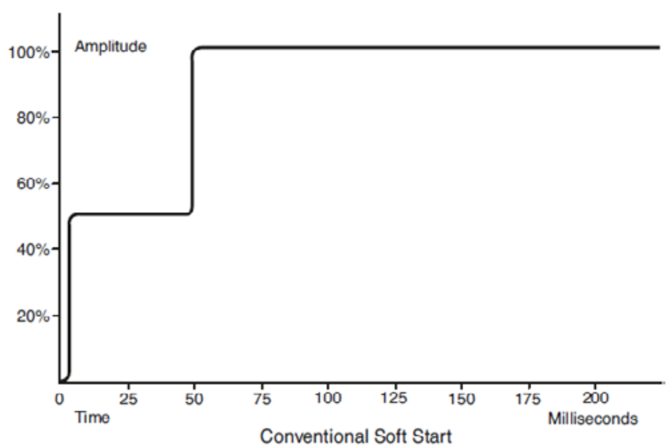


Figure 5-2 Conventional Soft-Start/Amplitude Graph

Although the conventional soft-start circuit improves the start-up problem, there is an inherent problem in its design: it still attempts to instantly accelerate the stack from at-rest to half amplitude, and then instantly accelerate the stack from half to full amplitude. Since it is physically impossible to instantaneously accelerate any mass, there are still surges in power from the generator and extreme stresses in the stack assembly during start-up and the shift from half amplitude to full amplitude. (**See Figure 5-3**.) The soft-start approach to start-up is somewhat like shifting gears on a manual transmission without using the clutch. Dukane generators incorporate design improvements that substantially reduce or eliminate the problems associated with the older, conventional soft-start design.

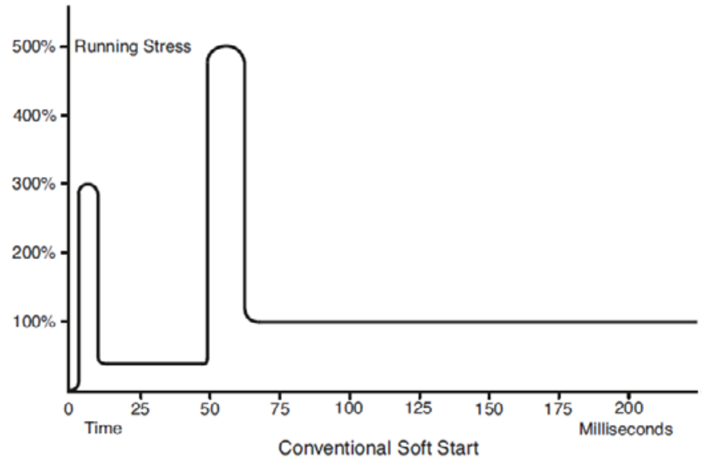


Figure 5-3 Conventional Soft-Start/Stress Graph

AUTO-TRAC TUNING

AUTO-TRAC tuning, an automatic frequency tracking feature, eliminates the need to initially match, or phase in, specific horn and transducer frequencies. AUTO-TRAC also compensates for changes in acoustic stack characteristics due to work-related heating, aging piezoelectric ceramics in the transducer, loading conditions, and differences in horn configurations. AUTO-TRAC operates with Dukane's sophisticated overload monitoring circuit to shut off the ultrasonic signal prior to subjecting components to abusive and damaging stress.

PULSE-WIDTH MODULATION

Figure 5-4 illustrates Dukane's patented Pulse-Width Modulation design feature, which employs a free-running phase lock loop circuit that is locked onto the sine wave feedback signal from the transducer.

The phase lock loop drives voltage comparator and logic circuitry that provides a pulse-width modulated square wave to the transistors in the power amplifier. By using the square wave form, the transistors are able to send more power to the load, while having to dissipate less heat energy. Not only does the generator run cooler, it also runs more efficiently

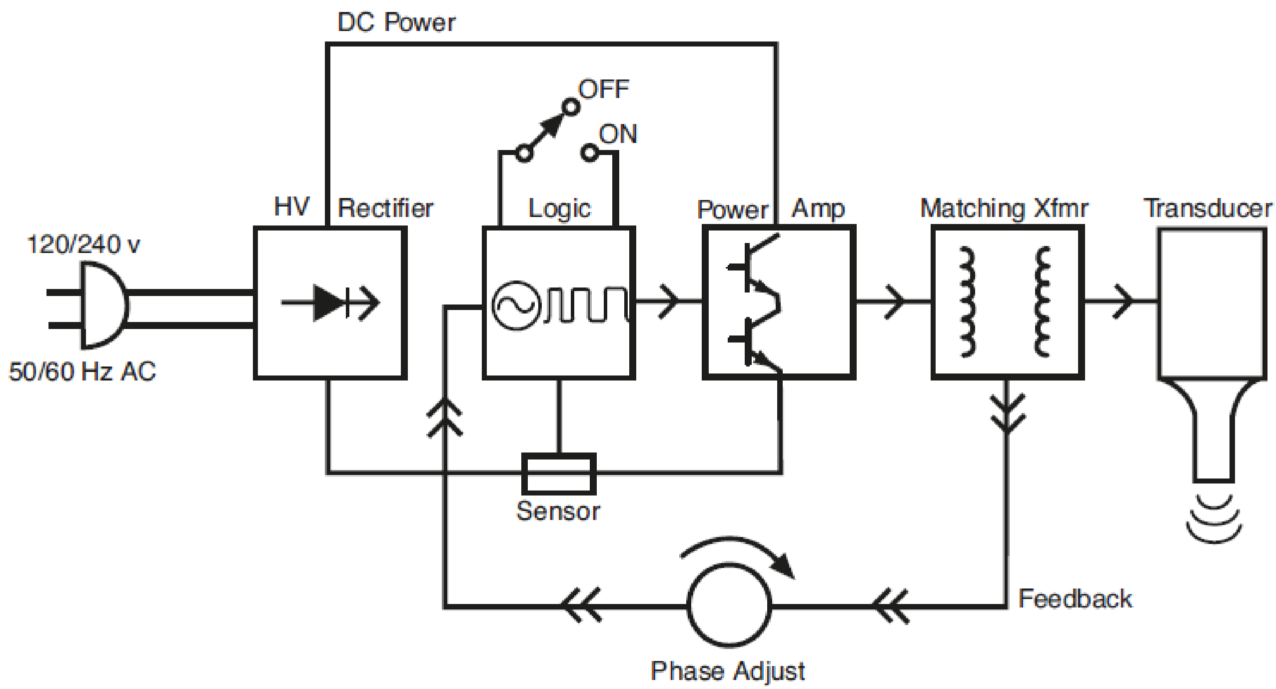


Figure 5-4 Phase Lock Loop Pulse-Width Modulated Circuitry

because its solid state circuitry eliminates the high voltage switching relay used in conventional soft-start systems. The reliability and life expectancy of the generator are increased.

The combination of AUTO-TRAC tuning and the operating characteristics of pulse-width modulated circuitry means correct frequency and phase operation occur immediately. The transducer's motion is monitored on a cycle-by-cycle basis, from the moment of activation, and the circuitry locks onto the correct operating point the moment motion is detected.

LINEAR RAMP VARIABLE SOFT START

The soft-start circuit in Dukane's pulse-width modulation design is also patented because of its unique start-up abilities. Dukane's Linear Ramp Variable Soft Start feature applies power and amplitude to start the stack assembly linearly, rather than in two, instantaneous jumps (surges). (**See Figures 5-5** and **5-6** on the following page.) In other words, it accelerates, or ramps, the stack assembly up to operating amplitude, eliminating start-up power surges in the generator and the shock stress in the stack assembly. Although the duration of the soft start time is set at the factory, it is variable and can be factory adjusted to custom suit the starting characteristics of a particular horn. Linear Ramp Variable Soft Start provides reduced stress and greater reliability for system electrical and mechanical components.

Dukane generators are also designed for ease of service, should it be necessary. All generator components carry generic markings and are not encapsulated, making all circuit boards easily diagnosed and repaired. All circuits are divided into modular units, which can be removed quickly and replaced with minimum effort.

MICROPROCESSOR CONTROL

Many generators contain a microprocessor-controlled digital timer that supports the mechanical functions of the pneumatic thruster. A digital timer can be thought of as the "brain" of an ultrasonic assembly system because it controls the up and down movement of the press/thruster slide assembly and turns on and off the ultrasonic energy produced by the generator. The timer stores lists of instructions, or modes, which it uses to control the plastics assembly system through a weld cycle. The user can alter a mode to select variations in the weld cycle by entering weld times, hold times, and various system parameters.

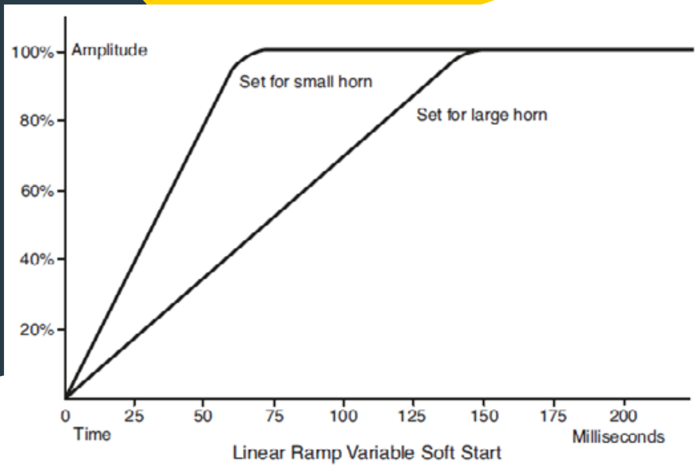


Figure 5-5 Linear Ramp Variable Soft Start/ Amplitude Graph

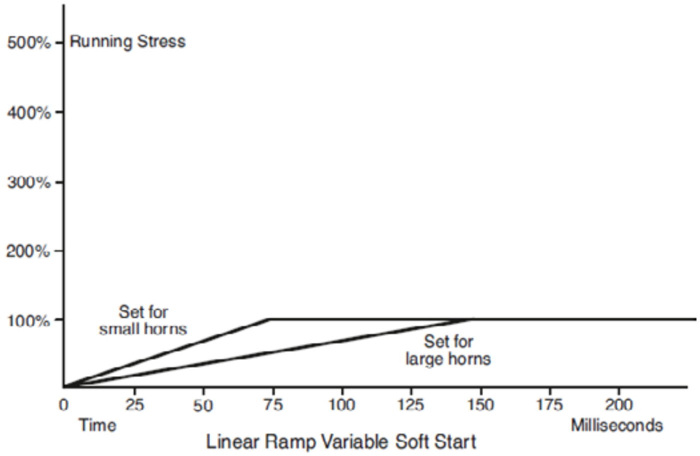


Figure 5-6 Linear Ramp Variable Soft Start/ Stress Graph

TRANSDUCERS

Transducers convert the electrical energy received from a generator into mechanical energy in the form of high frequency vertical vibrations. They accomplish this by using the principles of piezoelectricity, which is the generation of electricity or electric polarity by compressing a crystalline substance.

The heart of a transducer is the piezoelectric ceramic elements which, when exposed to electrical energy of alternating polarity, expand and contract dimensionally. As the electric polarity changes from positive to negative, the ceramic elements get thicker and thinner. Although this dimensional expansion and contraction is small, its force capability is great.

Note that the transducer's elements are made of a ceramic material. If they are dropped or subjected to excessive running stress (e.g., such as when a stack assembly is brought up to operating amplitude using the conventional soft-start method), they may shatter like glass.

As shown in **Figure 5-7**, the transducer driver assembly consists of the back slug, ceramic elements, and the front slug. Dukane transducers use a steel back slug and an aluminum front slug. Since the acoustical transmission properties of aluminum are far superior to those of steel, this arrangement directs as much vibrational energy to the booster and horn as possible. The amplitude of vibration at the output end of most 20 kHz transducers is eight tenths of one mil (0.0008 inches or 17 microns).

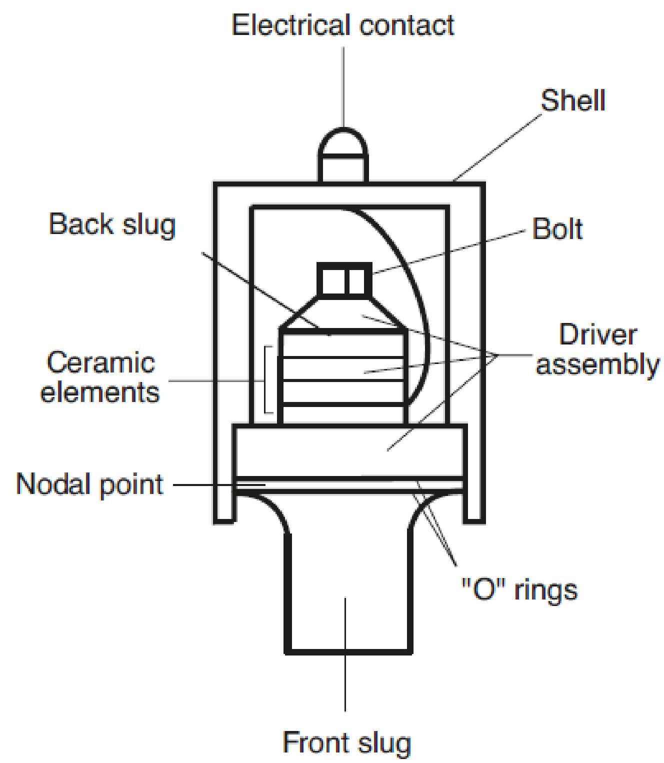


Figure 5-7 Ultrasonic Transducer

The digital timer makes several operating modes possible, giving a user flexibility in choosing the best mode to meet the application's requirements. Microprocessor control technology offers the added flexibility of multiple operating modes for precise process control, repeatability and weld consistency, better part quality, and fewer rejected parts.

There is an area near the center of the transducer where little or no motion occurs. This area is called the nodal point.

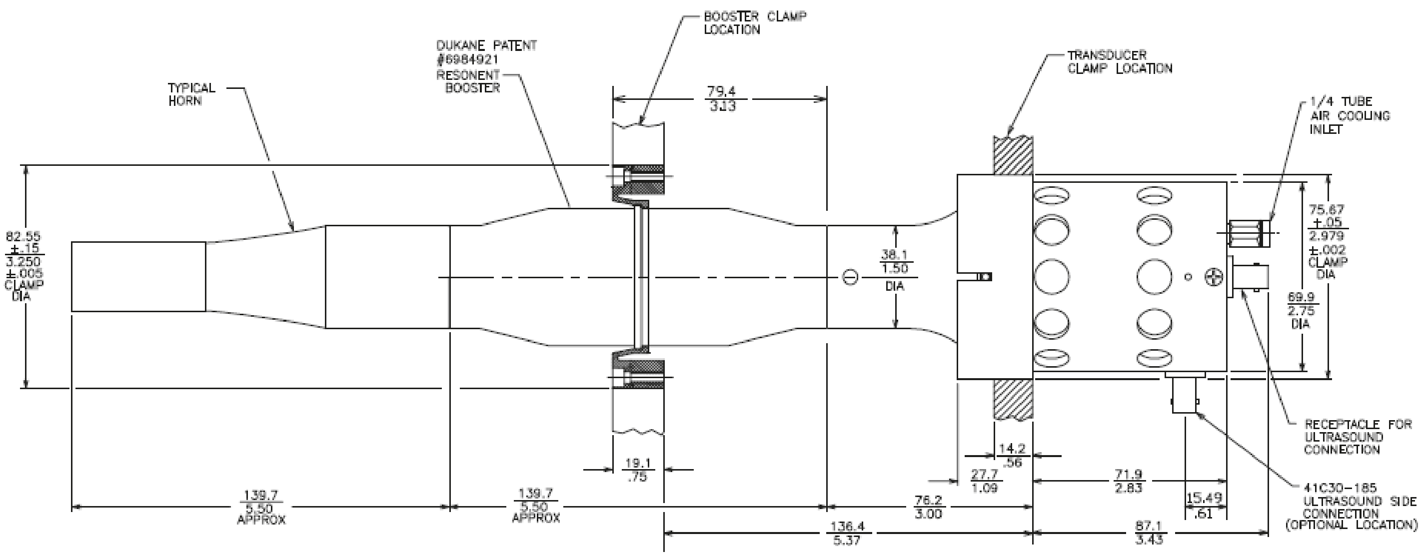
Although there is little linear motion at the nodal point, there is radial expansion and contraction, so it is an area under great stress. The lack of movement makes the nodal point useful for mounting the transducer in a shell. Neoprene "O" rings insulate the shell from any residual vibrations. Anti-rotational pins are installed through the shell into the nodal point to keep the ceramic element assembly, referred to as the "driver," from rotating inside the shell. The driver is assembled under tremendous compression (approximately 7,000 PSI) and held together with a steel bolt. There are no user-serviceable parts in a transducer. Defective units should be sent back to Dukane for repair or replacement.

In some cases it is desirable to mount a transducer solidly in a housing. Most often this is the case when space is limited and little sideways motion or flexing is allowable. This presents the problem of securely holding the vibrating transducer while allowing for radial expansion and contraction. The aforementioned O-rings do a good job of absorbing this radial motion, but they also allow compliance in mounting the front slug to a housing. To minimize this compliance, a variety of "solid" or "resonant" mounting arrangements have been developed. They are designed with thin metal walls which are tuned to vibrate at the transducer's natural frequency. By careful design and construction, these resonant mounts provide a good compromise of solid mounting and minimal power loss at the expense of increased manufacturing cost.

Below is a Table of Dukane's common transducer frequencies and the peak to peak amplitude output of each. Note that boosters and horns multiply this amplitude by a factor of 2 to 8 to provide the vibration necessary to do useful work.

FREQUENCY	PEAK TO PEAK AMPLITUDE
15 kHz	31 microns (.0012")
20 kHz	20 microns (.0008")
30 kHz	13.5 microns (.00053")
40 kHz	9 microns (.00036")
50 kHz	8 microns (.00031")

Table 5-1 Transducer Frequencies



NOTE:
DIMENSIONS ARE FOR REFERENCE ONLY.
HORN AND BOOSTER DIMENSIONS WILL VARY DEPENDING UPON HORN CONFIGURATION AND BOOSTER GAIN RATIO.

Figure 5-8 Two Mounting Points

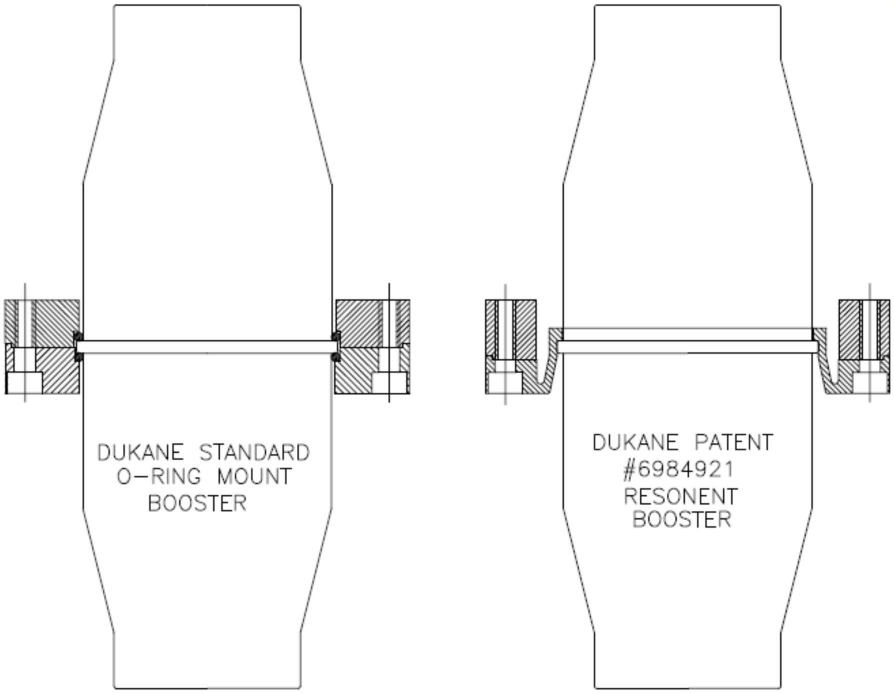


Figure 5-9 Standard and Resonant Boosters

BOOSTERS

Boosters serve two purposes: 1) Provide a second mounting point for the stack assembly, and 2) Either amplify or reduce the amplitude. Like the transducer the boosters have a nodal point, at the nodal point there is a mounting ring designed to fit into the press system or machine mount applications. See **Figure 5-8**. There are two types of mounting ring configurations. The standard boosters have a split mounting ring that houses two "O"rings in a similar configuration as the transducer. **Figure 5-9** shows a standard booster and a patented resonant booster. Patented resonant style boosters have no "O" rings. These are designed for applications where solid fixed mounting of the stack assembly is critical for the application. An example would be an application requiring two stack assemblies to weld a single part. Because of near proximity of the horns motion in the stack may allow them to touch, resonant boosters would eliminate this problem.

The boosters are either titanium or aluminum. Titanium boosters while cost more are more robust, stud thread holes hold up to many assembly and disassembly cycles. Continuous applications where heat dissipation is a benefit, aluminum boosters are recommended.

Boosters come in different "Gain" ratio's (**see chapter 5 Gain**) The mass of the booster below and above the nodal point determine the amount of gain to the amplitude from the transducer. This is the mechanical means for adjusting the stack amplitude to match the requirement to melt the particular plastic in each application. It is best to use the optimum booster size for the application, and leave the generator amplitude setting close at 100% and only making small generator amplitude adjustments when required. On most horns, the recommended max gain booster size will be stamped on the horn.

PRESSES

The primary purpose of the ultrasonic press is to apply the horn, and consequently the ultrasonic energy, to the workpiece in a controlled, repeatable manner. If the horn does not contact the part exactly the same every time, or if it is allowed to move (skate) on the part during the weld cycle, the results can be inconsistent and most likely unsatisfactory welds. One of the most important considerations of a press system is its structural integrity. Bases, mounting flanges, and columns made of steel have substantially less flexure than those made of aluminum. Flex contributes to inconsistency, which can mean more rejects and inefficient operations. **Figure 5-10** shows an ultrasonic press.

Figure 5-10 Ultrasonic Press

SLIDE ASSEMBLY DESIGN

The design of the slide assembly is also an extremely

important consideration in any press. Some slides have bronze bushings that are press-fit into the support casting, under a constant compressive load in the direction of the center. The inherent cold flow properties of bronze cause a gradual migration towards the center of the bushing's inside diameter, reducing the concentric contact between the bushing and the rod. As the contact area is reduced, the bushing wears rapidly. Slides of this design that have been run in production environments for a few years may exhibit so much play (i.e., "slop") that satisfactory production runs can no longer be maintained.

Migration problems can be eliminated if the bushings are held in place by some means other than a press-fit, and a very tight toleranceis held between the I.D. of the bushing and the O.D. of the rod. Without the compressive load, the concentricity between bushing and rod is maintained. The slide can run for years with virtually no wear.

A few manufacturers, including Dukane, offer presses that have linear ball slides. The main advantage of linear ball slides is that there is no clearance between a ball bushing and the rod. Operating friction is minimized.

Another design available on narrow profile 20 kHz Dukane presses is the rail-type linear ball motion system. While this slide also offers non-slip, accurate movement and virtually frictionless operation, its main advantage is its compact size. The size allows multiple welding heads (thrusters) to be placed closer together. Linear ball slide designs are the most durable and accurate available.

FORCE

The basic ultrasonic press is normally operated pneumatically with an air cylinder to provide the force required by an application. A gauge and regulator are used to control the amount of air pressure in the cylinder during the weld. (The actual clamping force applied to the work is calculated by multiplying the pressure reading on the gauge by the surface area of the piston.) Dukane also offers a method to electronically set and monitor the pressure and force levels through the use of an ultrasonic process controller, and a load cell, force transducer, and electronic pressure regulator. A flow control meters incoming air to adjust the speed of the downstroke. On many applications, a change in stroke speed alone will actually cause the weld on a finished part to change.

The amount of force applied to the work when the ultrasound is activated may also have a major effect on final welding results. Basic presses have some sort of dynamic trigger mechanism to vary trigger force. One particular method of dynamic triggering is shown in **Figure 5-11.**

The triggering sequence is as follows:

1. The horn contacts the workpiece. The die springs begin to compress as they are captured between the slide and the air cylinder.
2. The microswitch and the adjustable target make contact and the microswitch closure activates the ultrasonic energy.
3. The die springs assure that constant force is applied to the workpiece as the plastic melts down.

The dynamic trigger mechanism has three functions:

1. To enable the user to select the amount of force applied to the workpiece before ultrasonic energy is initiated.
2. To provide a switch closure to initiate the ultrasonic energy.
3. To maintain constant force on the workpiece via die spring reaction ensuring consistent energy transmission to the melt zone.

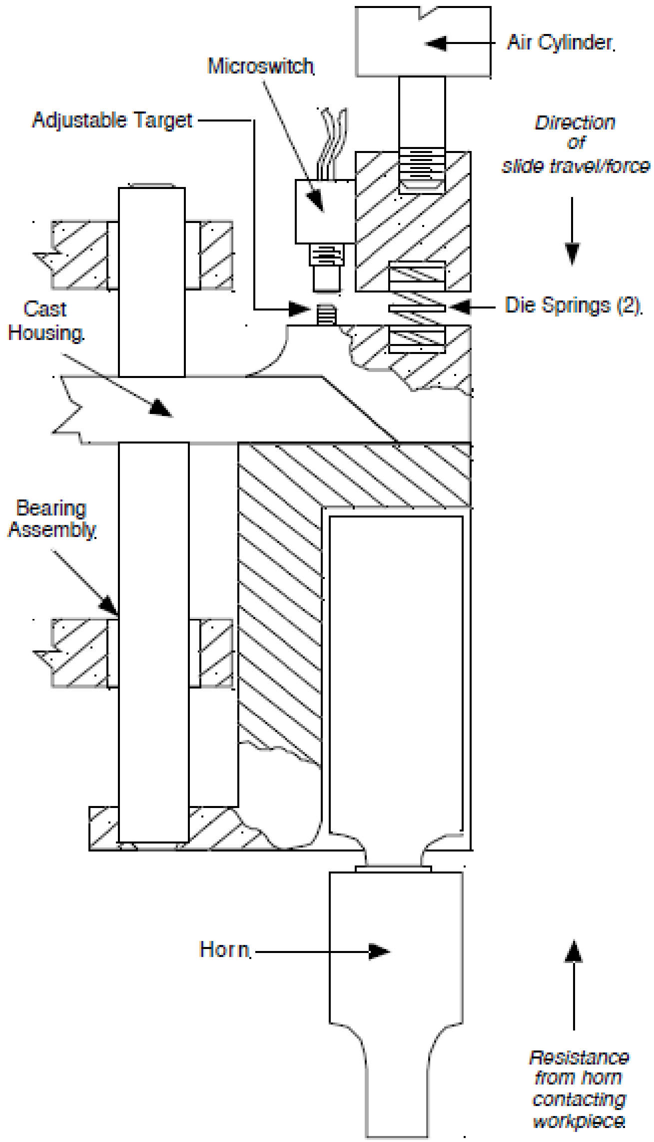


Figure 5-11 Dynamic Triggering

Advances in technology have led to more precise and repeatable methods of turning on ultrasound (triggering) in press systems. A strain gauge or piezo load cell may be used in place of the mechanical switch and actuating mechanism. With advanced digital control systems, the ultrasound can be triggered by a combination of load cell input, decrease in slide assembly velocity as the part is contacted or differential pressure changes in the air cylinder. Once ultrasound has been turned on, control over the force applied by the air cylinder may be by manual or dual air regulators. New electronic air regulators provide remote programming of force and permit multiple force setpoints during a weld. These advances contribute to better welds and more consistency in welded parts.

THE BOTTOM/MECHANICAL STOP

A bottom/mechanical stop adjustment is usually provided on a press to prevent the horn from accidentally contacting an empty fixture. The bottom/mechanical stop adjustment is also used to repeatably weld parts to a finished height. For most applications however, dimensional part tolerance variations will cause the amount of actual meltdown to vary even though the stroke is stopped at the same height each time. In situations where finished part height is critical, the bottom stop can be used to do it. However, it is difficult to set the weld timer to terminate the ultrasound at the instant the desired height is reached. Additionally, the hold force used during the weld cycle gets applied to the bottom stop rather than the part itself. Instead, the use of a microprocessor-controlled generator offering an Absolute Distance operating mode is recommended. Using the Absolute Distance mode or the end-of-weld limit switch on the press, ultrasound is terminated by height rather than time, assuring consistent finished part heights.

INTEGRATED VS. MODULAR PRESS SYSTEMS

There are two different types of press systems available today: the integrated system and the modular system. The integrated system is a self-contained unit, with the generator housed in the press. It is often less costly to manufacture than a modular system, takes up less space, and has no external cables. However, as with many packaged products, space and other design constraints present disadvantages that should be considered. In an integrated welder, the generator, which is an electronic device, is subjected during each weld cycle to the shock and vibration inherent in an ultrasonic press. Over a period of time, the shock and stress of the assembly process can adversely affect the generator's reliability and life expectancy. Should a problem occur with either the generator or a press component, the entire unit must be shut down, inconveniently halting production.

In a modular system, the generator is housed in its own separate chassis that is connected to the press with cables. A modular system allows the generator to be moved away from the press system, if requirements such as automation space limitations or hostile op-erating environments make it necessary. Modular systems do take up more space, because of the separate generator component, and they do have external cables. However, the increase in component reliability and longevity far outweigh their inconveniences. If a problem does occur with either the generator or press, the defec-tive unit can be replaced in a matter of minutes with a "loaner" or spare. Interruptions in production are minimized.

OTHER PRESS CONTROLS

Depending on the manufacturer, there are additional controls, offered as either standard or optional features, that can be of value for certain applications. Four of the most useful are a pre-trigger control, a hydraulic speed control, dual pressure, and an end-of-weld limit switch.

Some applications (e.g., staking and insertion applications) require the ultrasound to be activated before the horn contacts the workpiece. A **pre-trigger control** can be used to activate the ultrasound by horn travel distance during the downstroke, instead of using the dynamic triggering mechanism, which triggers the ultrasound by pressure or elapsed time. On Dukane presses, an optional pre-trigger end of weld kit is available. Using manually adjustable optical switches the pre-trigger position can be set. Another option with microproces-sor control, a distance encoder can be added to the Dukane press. Pre-trigger position can be programmed electronically through the microprocessor generator interface.

For certain applications, the stroke speed is so critical that it is extremely difficult to achieve consistency with just the pneumatic flow control. For these applications, a hydraulic speed control usually provides the means to perfect the welds, because it slows and precisely controls the down speed of the slide assembly just before and while the horn is in contact with the workpiece. The use of a **hydraulic speed control** minimizes weld cycle times by allowing for rapid slide descent until reaching the slow speed set-ting, providing precise control of material flow in the weld joint, and improving the finished appearance of staking and swaging ap-plications. Advanced press systems that use servo technology add a superior level of velocity control to achieve optimum accuracy.

Dual pressure is a feature that is exclusive to Dukane press systems. It increases clamp force to improve the plastic melt and flow during the weld portion of a cycle and assures tight assembly during the hold portion by welding parts at one pressure and hold-ing them together at a second, higher pressure. Dual pressure can also be used to begin a weld at one pressure, finish the weld at a second, higher pressure, then hold the assembly together at the second pressure. For more information about welding with dual pressure, see the Process Control section of this manual.

The **end-of-weld limit switch** terminates the ultrasound at a pre-determined distance from the slide's home position. For certain applications, especially when not using a process controller with a Distance function, using the end-of-weld limit switch to determine absolute weld distance is the preferred method, rather than using the bottom/mechanical stop (as previously mentioned).

PNEUMATIC AND SERVO COMPARISON

Dukane's research and develop-ment together with the need to meet increasing demand for assem-bly that is repeatable and precise has led to a wide range of creative joining solutions. These include both pneumatic and servo driven press systems.

Figure 5-12 ***iQ*** Servo Press System Front View

The basic function of a pneumatic press is to apply force between the parts using an air cylinder. The amount of force is generally con-trolled using a pressure regulator and one or more valves. Typical process control parameters avail-able to the user are ultrasound amplitude, weld pressure(s), weld time, hold pressure(s), and hold time. More advanced systems also have the ability to measure dis-tance, allowing a level of control of the weld and hold distances.

Servo systems are already taking parts assembly to higher levels of precision and repeatability. The Dukane ***iQ*** servo-driven welder is different from pneumatic systems because it utilizes an electrical servo actuator in place of the pneumatic cylinder. Instead of controlling the force, the servo sys-tem controls the speed of the horn during the weld and hold phases. Typical process control parameters are ultrasound amplitude, weld distance, weld speed (constant or profile), hold distance, hold speed, and static hold time. In the months and years to come, Dukane's commitment to prod-uct improvement will continue in developing industry leading assembly systems.

HORNS

The horns used for ultrasonic assembly are generally custom made to suit the requirements of a specific application and can be many different sizes and shapes. The purpose of the horn is to properly transmit the ultrasonic vibrational energy to the workpiece so that it localizes in the area where the melt is to take place. Many factors must be considered in the design of a horn.

GAIN

As is the case with a booster, the cross-sectional shape of a horn may give it a gain factor. That is, the horn may increase the amplitude of vibration it receives from the transducer-booster combination.

A straight-sided horn will have no gain usually (i.e., the gain ratio is 1:1) and little, if any, stress. **Figure 5-13** depicts a straight-sided horn. **Figure 5-14** shows an exponential horn, which has a low gain and low nodal stress; a catenoidal design, which has a medium gain and medium stress; and a step horn, which has a high gain and high nodal stress.

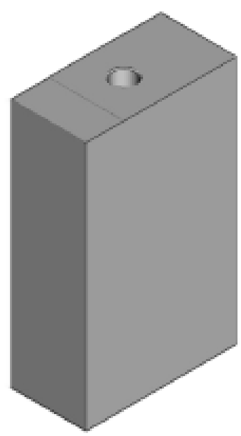


Figure 5-13 Straight-Sided Horn

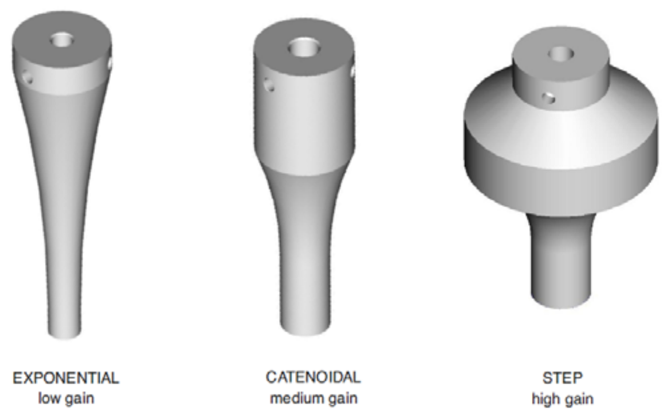


Figure 5-14 Exponential, Catenoidal, and Step Horns

HORN MATERIALS

A 20 kHz horn is typically a one-half wavelength long resonant bar, whose molecules are constantly expanding and contracting 20,000 times per second. Thus, the horn is continually under compression or tension. The horn actually stretches and shrinks in length, much like a spring. Since the horn must stretch, the material from which a horn is made is a major consideration. Horns are manufactured from aluminum, titanium, or steel because of each material's fatigue strength, acoustical properties, and surface hardness.

Aluminum has excellent acoustic properties and is a low-cost material. It is readily available in a wide range of raw material sizes and can be machined quickly and easily, reducing delivery time and labor costs. For these reasons, aluminum is often used to make prototype horns or horns requiring complex machining. Further, horns over 4.0" (101.6mm) in diameter or 11.0" (279.4mm) in width are generally made out of aluminum, due to its good acoustic properties, low material cost, and ease of machining relative to other materials. Aluminum's poor surface hardness and moderate fatigue strength can make it unsuitable for long-term, high-wear production applications. However, aluminum horns can be coated or plated with materials like chrome, nickel, or carbide to help alleviate these problems.

Titanium is generally the preferred material for horns because of its good fatigue strength, excellent acoustic properties, and good surface hardness. It is not always as readily available as other raw materials, nor is it always available in a convenient range of sizes. Titanium is also difficult to machine and is very expensive. Horns up to 4.0" (101.6mm) in diameter or 2.5" (63.5mm) in width and/or length (for rectangular or block horns) may be manufactured from titanium. For applications which require high amplitude and a hard surface, titanium horns can be coated with materials like carbide, nickel, or teflon.

For applications that cause severe wear, such as metal insertion, welding glass filled parts, and plunge cutting applications, CPM10V hardened steel horns can be used. The hardness of the CPM10V is RC 52-56. The most common CPM10V horns are our standard

Exponential, which are used for inserting. Due to the hardness of the CPM10V horns, this causes them to be more brittle; thus, they are usually used for low amplitude applications. There are horn size limitations, due to the brittleness.

In the past, Dukane used D2 steel for this type of application. Working with metallurgists and through experimentation, we discovered CPM10V to be more reliable.

SLOTS

Displacement amplitude at the horn face may vary as its length and/or width increases. Beyond a 4.0" (101.6mm) diameter or a 3.5" (88.9mm) length, side motion and transient frequencies require slots to be machined into horns. **Figures 5-15** and **5-16** show examples of slotted horns. Slots, in effect, break large horns into smaller, individual horns, to ensure uniform amplitude on the horn face and reduce internal stresses that may cause the horn to fail.

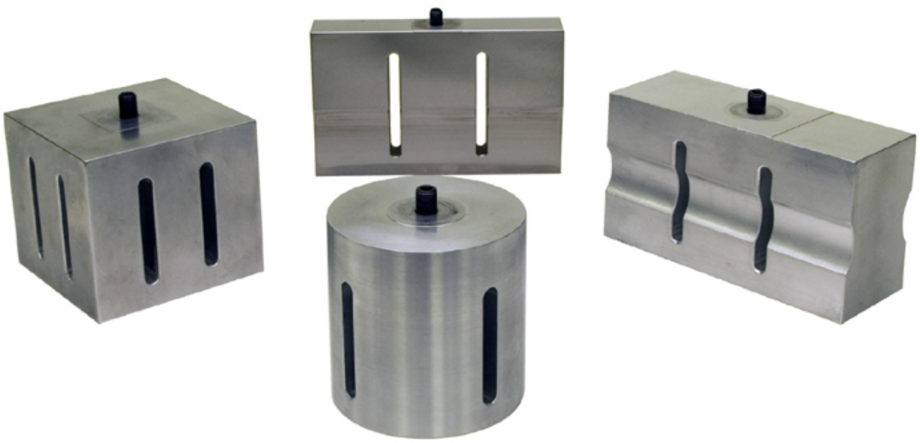


Figure 5-15 Exponential, Catenoidal, and Step Horns

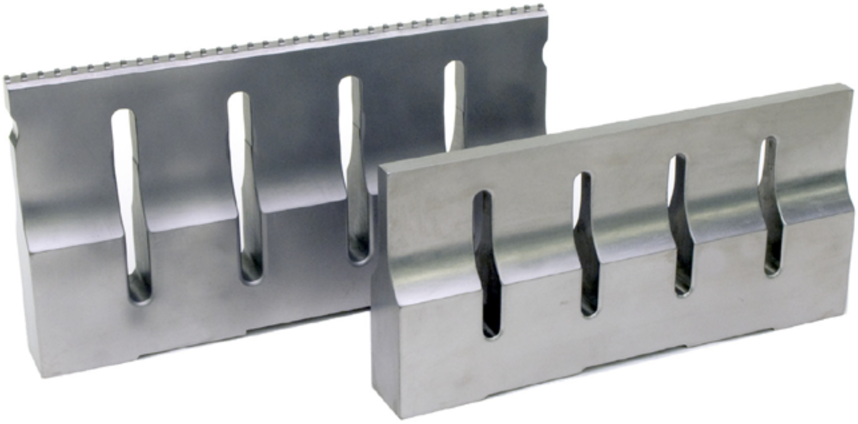


Figure 5-16 Slotted Bar Horns

COMPOSITE/COMPOUND HORNS

Ideally, the area of a part being contacted by a horn should be as close to the part joint as possible. At times, however, odd-sized parts may prevent a half-wave horn from either contacting the part where needed, or developing sufficient amplitude to weld the application. In these situations, use of a composite horn (also known as a compound horn) may be the answer.

A composite horn is really one horn or a number of individual horns (commonly referred to as "*horn tips*") attached to a coupling horn to form a single, tuned, full-wavelength unit. The large coupling horn may be made out of aluminum or titanium, as determined by the size and amplitude requirements of the application. The individual "working horns" could be made from either titanium or steel. The main advantage of a composite horn is that higher amplitude can be built into the horn without causing an excessive amount of stress. In essence, the amplitude at the face of a composite horn is substantially higher than what could be delivered by a single, large horn.

Composite horns have been used to solve the amplitude or wear problems encountered in large, multiple insertion, staking, and stud welding applications. They can provide greater part coverage, which in some cases can eliminate the need for multiple welders. When designing a composite horn, it should be thought of as a tuning fork, and its design and shape should be symmetrical and balanced. **Figure 5-17** shows a full-wave composite horn.

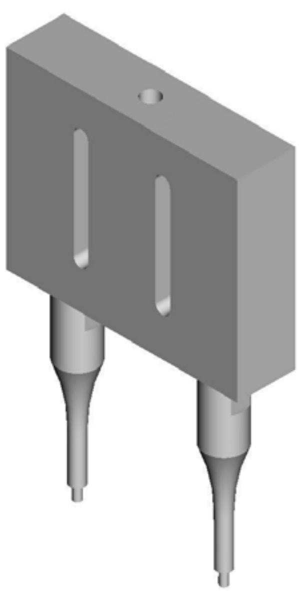


Figure 5-17 Full-Wave Composite Horn

CONTOURED HORNS

Because horn design has continued to progress along with part complexity, contoured horns are quite common. See examples of these types of horns below.

Computer 3-D design software is an important tool Dukane uses to design and produce precision horns that make superior welds possible.

Our contoured horns surround the part to be welded to maximize the function of the part's energy director. In addition, tooling of the horn is done to ensure that part integrity is maintained. Horn design is obviously linked to the fixture that holds the part. Both horn and fixture use design elements to keep the part securely in place.

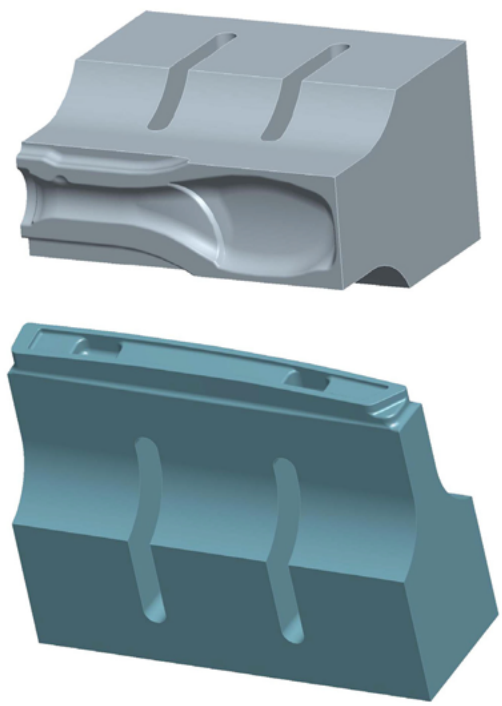


Figure 5-18 Contoured Horns

REPLACEABLE TIPS

For some staking and spot welding applications, a threaded, replaceable tip may be recommended. Replaceable tips thread into tapped one-half wavelength horns and enable worn tips to be replaced without incurring the expense of replacing the entire horn. **It is important to note that both the replaceable tips and the threaded horns must be made of titanium**. No other materials should be used. As a general rule, we do not recommended using replaceable tips with 40 kHz horns.

HIGH FREQUENCY (50, 40, 30 KHZ) HORN DESIGN

When designing horns to operate on 50, 40, 30 kHz equipment, there are more limitations to consider than when designing 20 kHz horns. Keep in mind that the velocity of energy is twice that at 20 kHz and in 40kHz.

As stated above, replaceable tips are also not recommended. Heat build-up is a bigger problem because there is less material available to dissipate the heat. Tuning is also more critical at 40 kHz.

Figure 5-19 Horns Threaded to Accept Replaceable Tips

TUNING

A horn is tuned to its correct operating frequency by using a horn analyzer. See Figure 5-20 below. The operating frequency (resonant frequency) of a horn is displayed electronically on a horn analyzer. The operating frequency of a horn is determined by the length of the horn from its input end to its output end (working face). Generally, horns are manufactured slightly larger than one-half wavelength long, and are machined down to a length that corresponds to their operating frequency (usually either 20 kHz or 40 kHz). Wavelengths are shorter as frequency rises. That is why 40 kHz horns are about half the length of 20 kHz horns. Finite

Figure 5-20 Horn Analyzer

ELEMENT ANALYSIS (FEA)

Finite element analysis software provides a powerful tool allowing our ultrasonic tooling engineers to test a horn design before it is sent to manufacture. This saves time and money while optimizing horn design and performance.

FEA helps the engineer accomplish these things:

1. Locate and analyze stress points.
2. Identify and minimize amplitude irregularities.
3. Optimize horn design to operate with a 20 kHz ultrasonic signal.

The figure below and the one on the next page illustrate that using FEA analysis optimized horn design, and that this analysis reduced stress, and amplitude variation respectively.

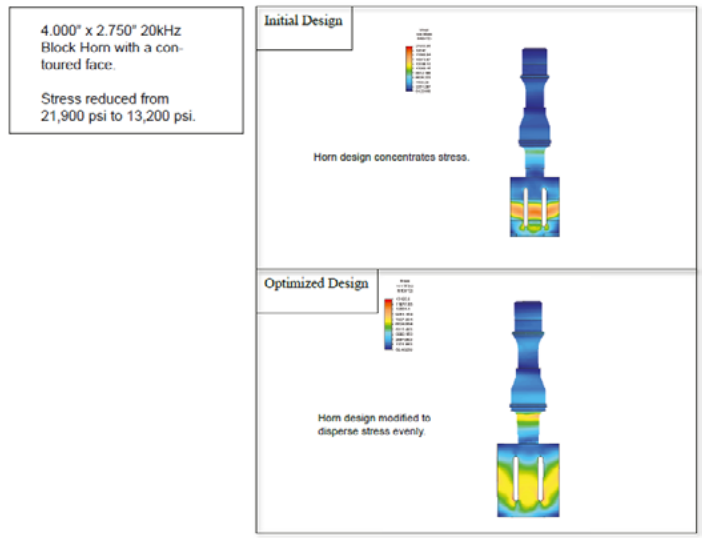


Figure 5-21 Horn Design to Reduce Stress

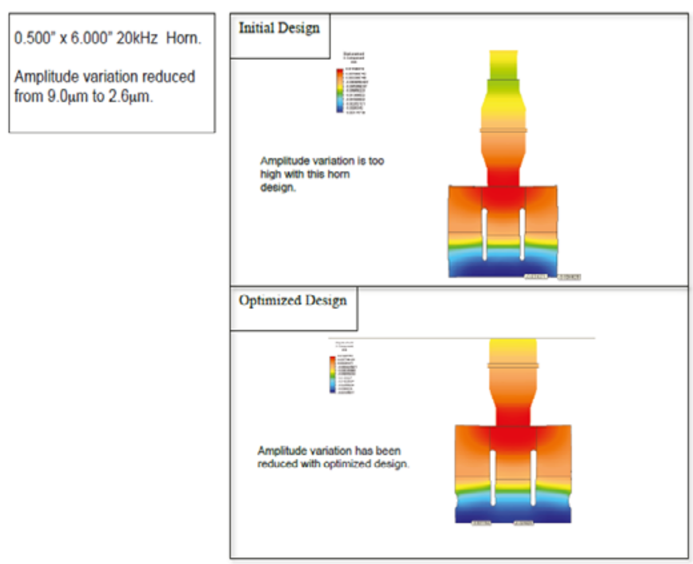


Figure 5-22 Horn Design to Minimize Amplitude Variation

FIXTURES

A fixture serves two purposes: alignment and support. It must align the part under the horn so that the welding process remains repeat-able. It must support the joint area properly so that the ultrasonic energy can be transmitted efficiently, ensuring good welds. As a guideline, a fixture should support an energy director joint up to just below the joint area. See **Figure 5-23**. For a shear joint, the fixture should fully support the joint area to prevent sidewall deflection. See **Figure 5-24**.

Fixtures are designed according to the requirements of each applica-tion, but two types are most common: resilient fixtures and rigid fix-tures. A resilient fixture is typically used for welding rigid amorphous materials that use an energy director. It is a poured or cast urethane material with elastic properties. A resilient fixture minimizes part marking and is less costly to manufacture than a rigid fixture, but it also absorbs more energy. **Figure 5-25** shows a resilient fixture. A rigid fixture is used when welding flexible materials that use either an energy director or a shear joint. A rigid fixture is used with all semi-crystalline materials. It should also be used when doing inser-tion, staking, swaging, or spot welding. Rigid fixtures are made of aluminum or stainless steel. **Figures 5-26**, **5-27** & **5-28** show rigid fixtures. **Figure 5-29** is a contoured fixture with release lever.

Like other ultrasonic system components, there are many things to consider when designing a fixture. Ease of loading for produc-tion, part material, type of joint design, welding technique, and cost are all factors. Since the horn and fixture are an integral part in the success or failure of an ultrasonic assembly application, it is recommended that they be manufactured by qualified, experienced ultrasonic engineers.

CAD PROCESS FROM DATA

As technology evolves, the design phase for fixtures and horns con-tinues to develop as well. An efficient design process for fixturing and horns involves data sharing between Dukane and its customers.

A typical project begins when customer part data, such as that produced by 3-D computer modeling software, is sent to Dukane's tooling staff. This data becomes the basis for the tooling needed to complete the fixture and horn hardware requirements of the project.

As parts become more elaborate in shape and contour, require-ments for horn and fixture design become more involved as well. The horn must contact the part's energy director carefully. At the same time the fixturing must have not only the basic cavity or nest for the part to support and align it properly, but also provide for whatever clamps, slide mechanism, or other devices are needed to securely weld the part.

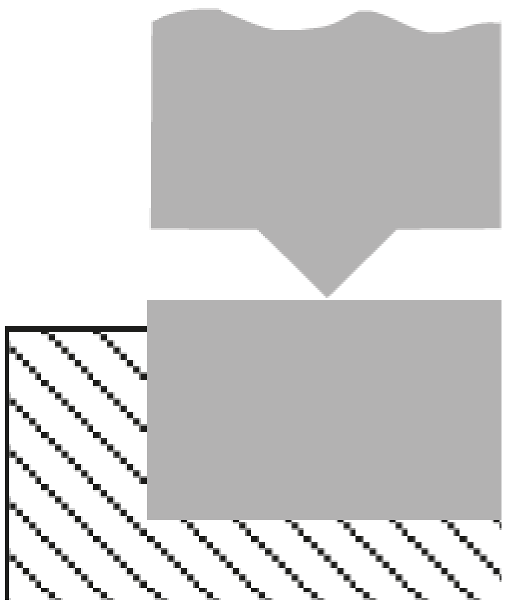


Figure 5-23 Fixturing an Energy Director Part

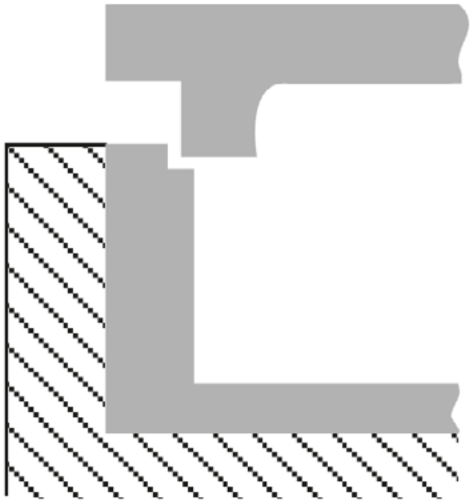


Figure 5-24 Fixturing a Shear Joint Part

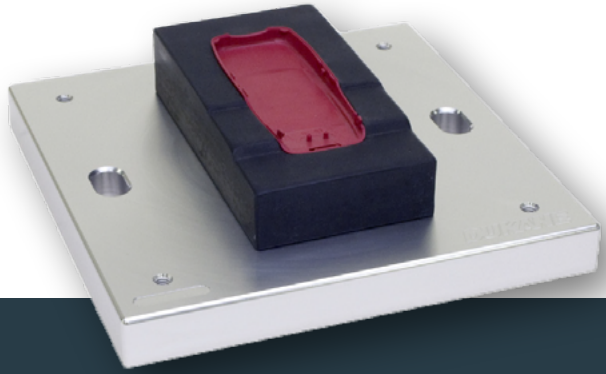


Figure 5-25 Resilient Fixture

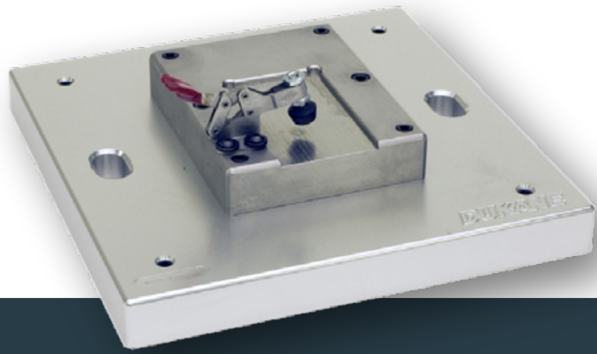


Figure 5-26 Rigid Fixture with Hold Down Clamp

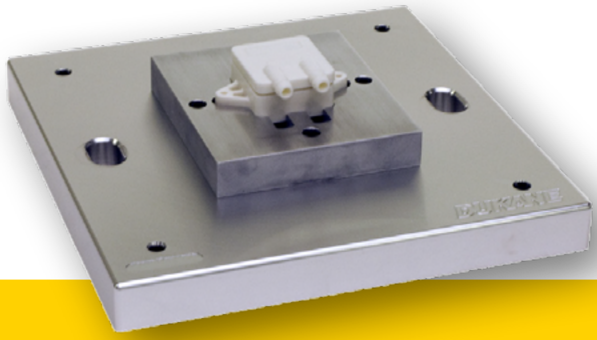


Figure 5-27 Rigid Fixture

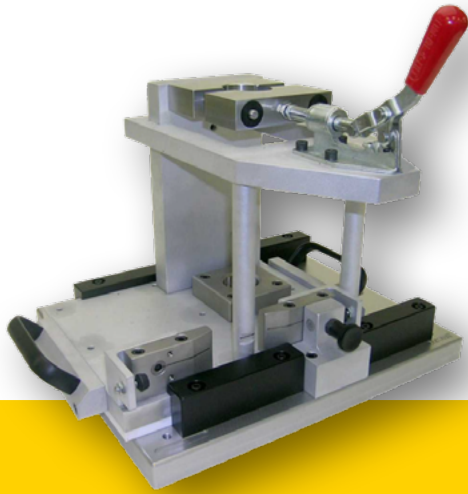


Figure 5-28 Rigid Fixture with Split Clamp

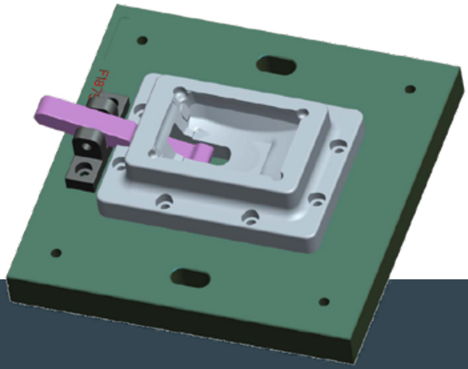


Figure 5-29 Contoured Fixture with Release Lever

PROCESS CONTROL

Chapter 6

WHAT IS PROCESS CONTROL?

Process Control is a method of evaluating and improving product and process quality on a continuous basis. Basically, it is a closed-loop process involving four steps.

1. Operate a process with at least one requirement. (A requirement is an expected condition that must be met to successfully complete a process.)
2. Measure at least one variable against its requirement during the operation of the process. (A variable is an item that may assume one or more values.)
3. Compare the measured result against the requirement.
4. Take corrective action, if necessary.

Process control can be referred to as a **closed-loop system** because it is a control system in which process data (feedback) can be used to maintain or correct output at a desired level. The feedback in this system is the data resulting from the comparison of a measured variable against that of its requirement. By contrast, an *open-loop system* is one in which no feedback is generated to provide for verification or correction.

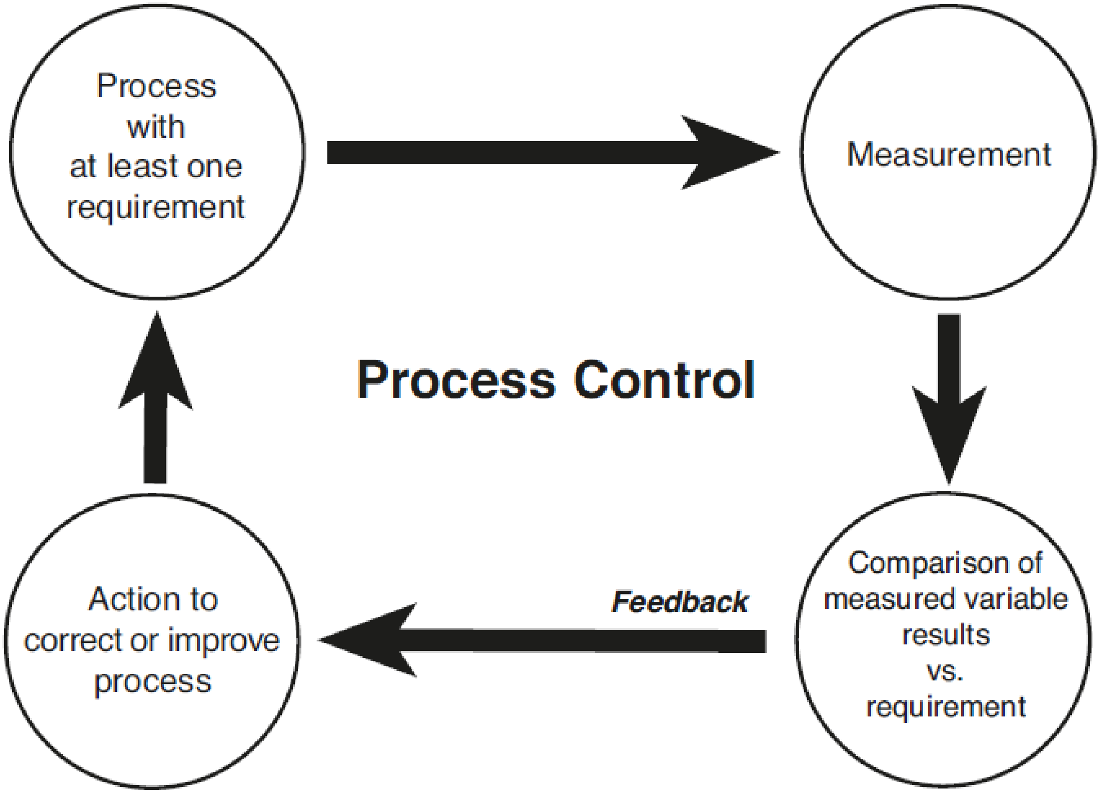


Figure 6-1 Process Control Model

OPEN-LOOP (TIME-PRIORITY) WELDING SYSTEMS

Open-loop, time-priority welding ("weld by time") is the oldest method used in ultrasonic plastics assembly. Parts are welded by a user-defined time duration.

When the system is activated, the horn descends until it touches the part. At that point, the ultrasound is turned on and stays on for a preset time. When that time elapses, the ultrasound is turned off and the head retracts. No process data is provided about the work being done. There is no efficient way to determine part quality and no way to tell if the process is in control. The welder goes through the same cycle whether the part is good or bad. In fact, the welder will go through that cycle even when there is no part in it at all. **Figure 6-2** represents an open-loop welding system.

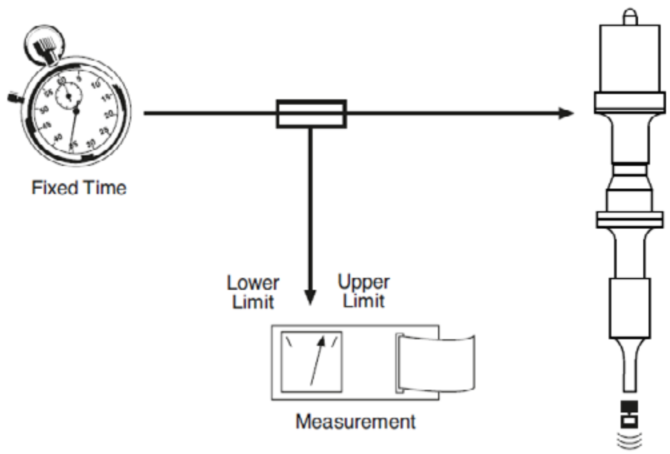


Figure 6-2 Open-Loop (Time-Priority) Welding System

Most ultrasonic equipment users are primarily concerned with consistency. They want to melt the same amount of material in the joint each time so that the strength of each assembly will be the same. The open-loop, time-priority method assumes that if the length of time the part is exposed to the sonic energy is always the same, then the amount of melt, and consequently the strength, will always be the same. However, this assumption is faulty. Inconsistencies in the parts due to things like mold cavity variations or using different resin grades assure parts will be anything but consistent.

CLOSED-LOOP (ENERGY-PRIORITY) WELDING SYSTEMS

Closed-loop, energy-priority welding ("weld by energy") was developed to address the inconsistency and lack of feedback in the open-loop, time-based method. Parts are welded by the amount of energy they absorb.

When the system is activated, the horn descends until it touches the part. At that point, the ultrasound is turned on and stays on until a preset energy level (in joules) is reached.

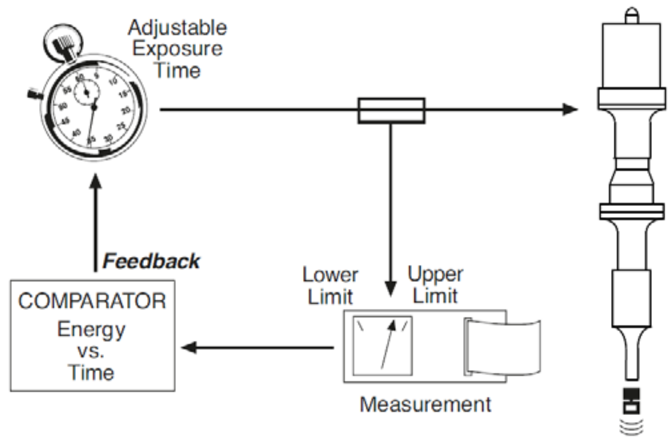


Figure 6-3 Closed-Loop (Energy-Priority) Welding System

When that happens, the ultrasound is turned off and the head retracts. **Figure 6-3** represents a closed-loop, energy-priority welding system.

The system determines energy by multiplying the power drawn by the part by the length of time the ultrasound is on (exposure time). The system is a closed-loop system because it measures the power being drawn and adjusts the exposure time so that the resulting energy level is reached. For parts that draw low power, the time is increased. For parts that draw high power, the time is decreased. The closed-loop, energy-priority method assumes that if the energy consumed during the weld is the same each time, then the amount of material melted in the joint will be the same each time.

Experimentation has proven that constant energy does not produce a consistent melt any more than does constant time. Again, inconsistencies in the part, coupled with energy losses in the ultrasonic equipment, render the energy assumption invalid. **Figure 6-4** explains the energy losses that can be experienced in the welding process.

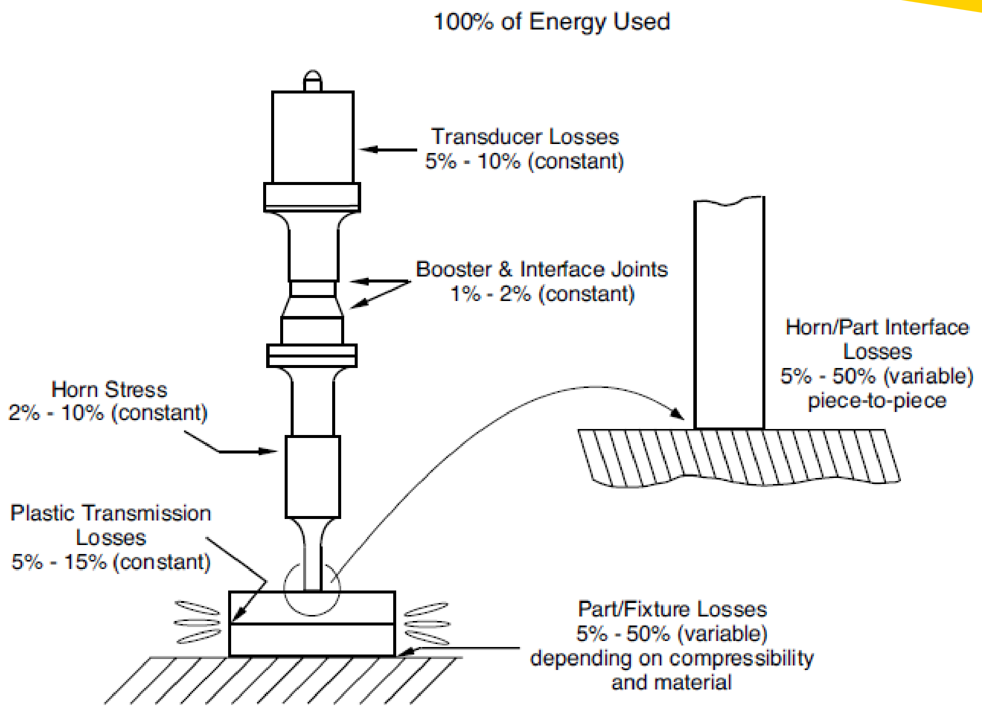


Figure 6-4 Energy Losses in the Ultrasonic Welding Process

The energy lost in the transducer-booster-horn combination and the transmission properties of the plastic are relatively constant and can be compensated for. However, the energy lost at the interface between the horn and the part and between the part and the fixture can vary from five to fifty percent each, depending on how the individual part fits the tooling. Since the size and the shape of molded plastic parts can vary from piece to piece, there is little correlation between constant energy and consistent results.

MICROPROCESSOR CONTROL

As we have seen, prior to the manufacture of computer-controlled ultrasonic welding equipment, the welding process could only be controlled by time. No process data was generated and there was no reliable way to verify part quality short of destructive testing or time-consuming 100% inspection.

With the advent of computer-controlled equipment, data from the ultrasonic process became available and ultrasonic plastics assembly equipment manufacturers began incorporating process control features into their equipment. Among the many new things that microprocessor technology made possible were:

- The ability to gather and log data for statistical process control (SPC) analysis
- More efficient automation and system integration
- Reduced setup time by storing multiple setups
- Control and monitoring of process variables on a cycle-by-cycle basis
- Verification of process and part quality through such measures as weld time, depth of melt distance, peak power, energy consumed, melt velocity and finished assembly height

As more high-performance plastic resins continue to be developed, assembly techniques likewise continue to be refined and developed. Both demand highly controllable and precise joining methodology. The feedback data from welding process variables make possible higher finished product quality, fewer rejects, and documented process results.

The ***iQ*** can weld by constant time or energy should a user wish to do so, but its microprocessor-based technology makes it capable of so much more. The following paragraphs explain some of the enhance-ments to the welding process made possible by the ***iQ***.

ELECTRONIC PRESSURE REGULATION

Electronic pressure regulation provides electronic setting, control, and monitoring of press air pressure using an electronic pressure regulator and a pressure transducer. An electronic pressure regulator is the electro-pneumatic equivalent of the manually adjustable air regulator on the press head. It converts an electronic signal into an air pressure, which the ***iQ*** uses to set and control air pressure during the weld.

The pressure transducer is the equivalent of the press air pressure gauge. It converts pressure into an electronic signal, which the ***iQ*** uses to monitor the air pressure during the weld cycle. During the welding process, the ***iQ*** logs pressure measurements and can generate pressure vs. time graphs on demand.

LOAD CELL (FORCE TRANSDUCER)

The load cell or force transducer is a device that measures force. It converts mechanical force into an electronic signal, which the ***iQ*** uses to activate, or trigger, the ultrasonic energy at very precise user-defined force levels. During the welding process, the ***iQ*** samples force measurements and can generate force vs. time graphs on demand.

REMOTE SETUP SWITCHING

Remote setup switching enables the ***iQ*** to change setups in response to a signal from a programmable logic controller or other exter-nal source. It minimizes setup changeover time and increases the flexibility of automated production systems.

SEQUENCING

Sequencing refers to the ***iQ's*** ability to change setups after a user-defined number of welding cycles, or in response to user inputs from a programmable logic controller or sensor. It is designed for applications where a part requires more than one set of operations to be performed on it and each set of operations requires different setup parameters. The ***iQ*** is the industry's only process controller to offer sequencing.

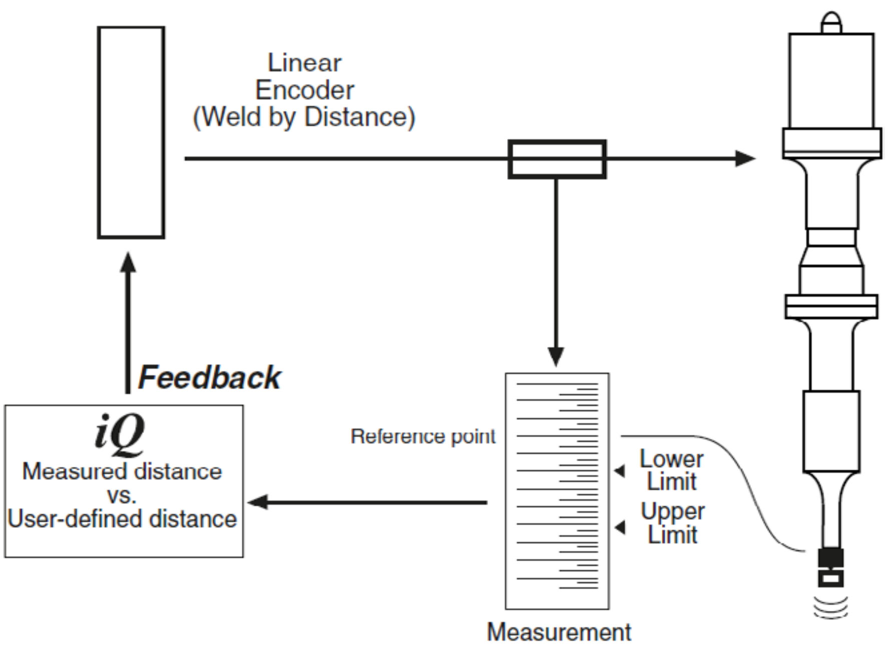


Figure 6-5 Closed-loop (Dimension-Priority) Welding

WELD BY DISTANCE

When a linear encoder is mounted to a press system, the ***iQ*** is able to set and measure very precise distances. Because the ***iQ*** is able to log such precise distance measurements, the system can join plastic components by a specific weld depth. This welding technique is known as "weld by distance."

When the system is activated, the horn descends normally until it contacts the part. The ***iQ*** then marks that distance as the reference point, thereby eliminating all part tolerance variations, and welds the pieces together to a user-defined distance. This virtually guarantees that the same amount of material in the joint will be melted each time. The reference mark resets the ***iQ*** distance register each cycle ensuring consistent, repeatable results every time. **Figure 6-5** illustrates the principle of weld by distance.

DUAL PRESSURE

The conventional welding process welds and then holds part assemblies at the same pressure. Dual pressure allows greater flexibility in the welding process by offering two alternatives: weld at one pressure (Pressure 1) and hold at a second pressure (Pressure 2) or weld at two different pressures (Pressure 1 and Pressure 2) and hold at the second pressure (Pressure 2). For many applications, there is an advantage to initiating the weld under a low pressure, then increasing the pressure to finish the weld. Applications that have proven otherwise unfeasible run satisfactorily using a dual pressure welding method. Dukane Corporation's ***iQ*** is the industry's only process controller capable of setting and controlling dual pressure welding.

iQ SYSTEM FEATURES - SERVO

The ***iQ*** Servo system, because it is unlike a pneumatic system in several ways, offers an alternative to traditional joining techniques. With Dukane's standard, patented features in its servo systems, quality welds, and consistent results make these systems an excellent choice.

SENSING START DISTANCE AND SENSING SPEED

These pre-weld features can be considered together. They are essential to any setup, and are part of the triggering sequence for the servo system. The figure below shows a partial ***iQ*** Explorer screen image in which presets for Sensing Start Distance and Sensing Speed have been made.

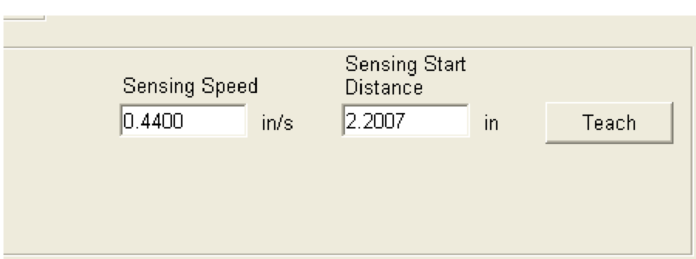


Figure 6-6 iQ Explorer - Setting Sensing Start Distance and Sensing Speed

NOTE: *If trigger type is by Absolute Distance, Sensing Start Distance and Sensing Speed are not used.*

From the home position, the press system's horn lowers quickly. The horn slows to the Sensing Speed that begins slightly before reaching the Sensing Start Distance. The effects of deceleration and servo tuning can be settled by the time the thruster gets to Sensing Start Distance. This is a distance just above the part to be welded.

Then, the horn continues until it reaches the programmed trigger value (force or power). At that point, the ultrasonic signal is turned on, and the horn moves at a programmed speed through the weld cycle.

NOTE: ***iQ Explorer*** *software is a Dukane program that enhances any compatible* ***iQ*** *Series ultrasonic generator through a user interface that allows monitoring and setup to be done virtually anywhere.*

START MOTION AT FORCE DROP

Start Motion after Force Drop identifies a point in the weld cycle when several things are happening at once.

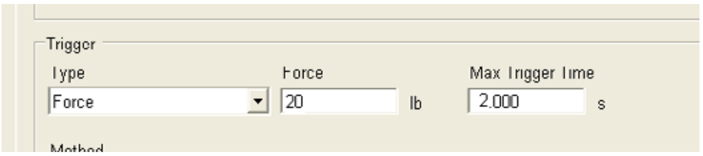


Figure 6-7 iQ Explorer - Setting Force Drop In Relation to Trigger

When the programmed trigger force value is reached, (**Figure 6-7** shows a partial image of an ***iQ*** Explorer programming screen.) the thruster's downward movement stops and the ultrasound signal starts. Next, a programmed drop in force is detected – indicating that the parts have begun to melt – and the weld continues as servo motion restarts. Part compression continues for the programmed distance and speed.

WELD MOTION TYPE

This feature refers to the way in which the speed is distributed during the weld cycle. There are two choices – Constant, and Profile.

Constant – As soon as the welder triggers, the horn travels at a constant speed throughout the entire weld cycle.

Profile – Speed can be profiled, or customized, in as many as 10 steps during the weld. If welding by distance, the total collapse distance would be divided into 10 equal segments. A different speed can be programmed for each of the segments.

In using this feature with an unfamiliar plastic, perhaps start with Constant while the responsiveness of the material becomes apparent. Then switch to Profile allowing the operator to fine-tune the speed.

When there is an energy director that is intricate or complex, a multi-step weld may be required to achieve an acceptable result. Perhaps a part of the director might be thin, and another part might be thick where weld velocities could be profiled to suit this particular application.

HOLD

This is a post-weld operation. As with a pneumatic system, Hold is a period of time after the ultrasonic signal has been turned off when the molten polymer is compressed together as it solidifies and shrinks to prevent or reduce residual stress and voids in the bond area. Programming a hold with the ***iQ*** Servo Press allows for these hold sequences: Dynamic, Static, or a hold that uses both dynamic and then static hold.

Dynamic Hold – The press continues to compress the parts after the ultrasonics has turned off, further collapsing the parts.

These are the parameters to program for Dynamic hold: Hold Collapse Distance, Hold Speed and Max Hold Time. The time parameter is set in case either of the other values are not met.

Example – As in the melting phase, the solidification phase of an amorphous material is generally more gradual than semi-crystalline materials. Using Dynamic Hold offers more fine-tuning capabilities for the different material groups. As a general starting point for the hold cycle speed for amorphous materials, the Dynamic Hold Speed should be set at a value equal to or less than the final Weld Speed. For semi-crystalline materials, the Dynamic Hold Speed should be set equal to or greater than the weld speed.

Static Hold – The press holds its final weld position for a given amount of time, without moving, while the material solidifies. The horn then returns to the home position or top of stroke ready for a new cycle.

This feature may be useful for thin-walled parts where the collapse distance is small.

TEACHABLE TOP OF STROKE POSITION

After completing a weld cycle, the welder's thruster returns to its top of stroke position, ready to start another cycle. With the ***iQ*** Servo press, that position can be directly programmed, or the position value can be taught.

To teach the welder, the dual opto-touch switches are used to jog the press into position. Then the operator uses the computer interface that displays a TEACH button to "Set This Position", and the information is automatically entered as the top of stroke position.

POSITION TEACHING

The top of stroke position is not the only position that can be taught during your welder's setup phase. Sensing Start Distance, Mechanical Bottom Stop, are examples of other teachable positions.

As with top of stroke positioning, the software leads the operator through all of the programming possibilities with its use of pop-up screens, and TEACH buttons.

NOTE: *Although Sensing Start Distance can be programmed numerically, some prefer to set this position manually. The press can be manually jogged down to a point where the horn is close to the part that will be welded. When a suitable distance is reached, the operator can press the SET button on the computer interface to record that distance value.*

SETUP SWITCHING

A setup contains all the programmed parameters for one particular process. On an ***iQ*** Servo press the setup can be saved digitally in memory. All settings, including the home position, speed control, top of stroke and others are saved as part of a particular setup.

NOTE: *The only mechanical adjustment that might be needed is if the thruster had to be repositioned on the column for some reason. If the press is moved up or down, when going to a new program Sensing Start Distance and Mechanical Bottom Stop have to be reset.*

If welding a high volume of parts, repeatable results is the goal, then it is very likely that many machines will be welding parts simultaneously.

DUPLICATING PROCESS ON MULTIPLE MACHINES (CLONES)

With the ***iQ*** Servo, multiple machines (welders) can be programmed to duplicate a known process. With pneumatic systems this presents a dilemma because of all of the minor mechanical differences that exist from welder to welder.

Figure 6-8 ***iQ*** Servo Press Cloned Systems

iQ SERVO SYSTEM BENEFITS

The ***iQ*** Servo system has a number of differences in its features as compared with our pneumatic systems as explained in the paragraphs above. Typical servo systems have some advantages over the pneumatic systems. These benefits are outlined in the text below.

WELD AND HOLD COLLAPSE DISTANCES CONTROL

There is significantly more precise control of the weld and hold collapse distances, which stems from the underlying method of distance control. In pneumatic systems, the distance is controlled indirectly by relieving pressure from the air cylinder once the desired distance is achieved. Due to the limited rate at which compressed air can escape the cylinder as well as other factors, the press typically travels beyond the desired collapse distance by varying amounts. Conversely, the servo system controls the distance directly through the closed-loop servo position control; that is, the servo dynamically seeks to arrive at the desired position, yielding very precise and repeatable results.

RAPID SPEED CHANGE

In certain applications, it is desirable to profile the speed during the weld in order to match the natural rate of melt of the material. Since most ultrasonic welds are under 0.5 s in duration, it is critical to change speed quickly to achieve meaningful weld profiling behavior. The servo system is capable of accelerations of 50 in/s2, which is equivalent to changing speed by 1 in/s. in 0.020 s.

The ability to program independent speeds for up to 10 different segments of the weld, along with the servo system's feature of dynamically sensing when melt is being initiated at the beginning of the weld process, is termed Melt-Match® technology. Although some pneumatic systems are capable of varying the force during the weld, the rate of change is restricted due to the time required to move air in or out of the air cylinder. Rapid speed changes on the servo welder also afford the flexibility to achieve hold speeds which are substantially different from the weld speeds.

VERSATILITY

Versatility is another key advantage of servo systems. Some applications, which have been deemed very difficult if not impossible to achieve on a pneumatic welder, have been successfully executed on a servo system. One example is the sealing and cutting of thin film media, where the weld distances and forces are quite small. With precise distance control, the servo system was capable of achieving quality welds.

HOLD PHASE

There is enhanced control capability of the hold phase, which consists of a dynamic stage (parts are collapsed further after ultrasound is turned off) and a static stage (servo maintains its final position allowing the solidification process to finish).

EASE OF CALIBRATION

Ease of calibration because pneumatic components have been eliminated.

WELDER CLONING IS EASIER

Ease of welder cloning is improved due to digital process control (i.e., ability to set up multiple welders to achieve the same performance).

If welding a high volume of parts, repeatable results is the goal. Very likely many machines will be welding parts simultaneously. With the ***iQ*** Servo, multiple machines (welders) can be programmed to duplicate a known process. With pneumatic systems this presents a dilemma because of all of the minor mechanical differences that exist from welder to welder.

REJECTS REDUCED

Due to the high degree of process repeatability, the number of rejects can be reduced. This enhanced ability to maximize yields is especially important in cases where the assembled parts are of high value.

SMALLER MAINTENANCE COST

The elimination of compressed air for press actuation can also produce savings. A typical 40-hp compressor can cost approximately $13,000/yr to operate. In addition, the expected maintenance costs are smaller. In typical applications, the servo actuator has a life span in excess of 200 million cycles.

FEWER ACCIDENTAL CHANGES

To ensure process repeatability and maintain calibration, the servo system is designed without adjustable mechanical operator controls on the machine. This prevents accidental or unauthorized changes in calibration and validation.

GLOSSARY

Amorphous Plastic	A plastic with a random molecular structure.
Amplitude	The peak-to-peak excursion of a horn or a booster at its workface.
Booster	A mechanical transformer used to increase or decrease the amplitude of the horn.
Boss	The hollow stud into which an insert is driven.
Colorants	Liquid or dry pigments that are added to resins to make different colors of plastics.
Coupler	A booster that does not affect the amplitude of the horn. Its gain ratio is 1:1.
Dampen	To mechanically limit the amplitude of vibration in the parts being assembled.
Degating	A process by which injection molded plastic parts are separated from their runners at the gate.
Diaphragmming	Part flexing that can cause stress, fracturing, or undesirable melting of thin-sectioned, flat parts. Diaphragmming is also referred to as “oil-canning,” which describes the way the plastic part bends up and down when subjected to ultrasonic energy.
Digital Timer	A device used to control the duration of a weld or a hold time.
Dual Pressure	A feature of Dukane assembly systems that allows the use of two different pressures during the assembly process.
Energy Director	A triangular-shaped bead of plastic molded into a part and typically running around the entire perimeter of a joint. When ultrasonic energy passes through the part, it concentrates the energy at the energy director’s apex, resulting in rapid heat buildup and melt.
Far Field	Refers to the distance that ultrasonic energy is transmitted from the horn to the joint interface. When the joint is more than 1/4"(6.4mm) from where the horn contacts the part, the weld is considered far field. (See Near Field.)
Filler	An inert substance that is added to a resin to modify its physical characteristics.
Fixture	A device used to align and support the parts to be assembled. It is sometimes referred to as a nest.

Flame Retardant	A substance, such as boron or phosphorous, which is added to a resin to alter its combustible properties.
Flash	The overflow of molten plastic from the joint area.
Force Drop	This variable pressure is determined during system setup. The drop (decrease) in pressure indicates that parts are beginning to collapse and bond. A range between 5% to 10% of the trigger force value is a good place to begin in setting the Force Drop.
Frequency	Number of cycles per second ususally expressed in kilohertz (kHz).
Gain	The ratio of output amplitude to input amplitude of a horn or a booster.
Gate	The area through which molten plastic flows into the mold cavity. See also Degating.
Generator	An electronic device that converts standard 120/240 volt, 50/60 Hz line voltage into high-frequency electrical energy.
Hermetic Seal	An air-tight and liquid-tight seal.
Hold Time	The length of time allotted for the melted plastic to solidify.
Horn	An acoustical tool designed to transfer mechanical vibrations from the transducer-booster assembly directly to the parts to be assembled.
Hygroscopicity	The tendency of certain thermoplastic materials to absorb moisture from the air. Nylon is a hygroscopic thermoplastic.
Insert	A metal fastener designed to be installed in a plastic part.
Insertion	An ultrasonic assembly technique that embeds a metal insert into a plastic part.
Joint Design	Molding the shape of mating thermoplastic parts to achieve the intended assembly results. Proper joint designs provide a uniform contact area, a small initial contact area, and a means of aligning the mating halves to be assembled.
Lubricant	A substance, such as wax or stearic acid, which is added to resins to improve their flow characteristics and enhance processability.
Marking	Cosmetically scuffing or marring of plastic parts by the horn or the fixture.
Mold Release	A substance added to plastics so that parts are easily removed from the mold.
Multiplexer	A device that is capable of receiving information from many sources and transmitting it over one, common communications medium.

Near Field	Refers to the distance that ultrasonic energy is transmitted from the horn to the joint interface. When the joint is1/4" (6.4mm) or less from where the horn contacts the part, the weld is considered near field. (See Far Field.)
Nodal Point	The point or points in a booster or a horn where little or no linear motion occurs.
Piezoelectric Material	A ceramic material that changes dimensions when electrical energy is applied.
Plasticizer	A substance added to plastic to increase its flexibility.
Pneumatic	Air-powered, operated, or controlled.
Polymer	A chemical compound or mixture of compounds formed by a chemical reaction of two or more molecules. Polymers are also called resins.
Press	A pneumatic or servo driven device used to transport the acoustic stack assembly to the work in a controlled and repeatable manner. It is essentially a thruster mounted on a column, press support casting, and a base. (See also Thruster.)
Regrind	Plastic material that has been recycled or reprocessed and added to the original resin.
Replaceable Tip	A machined titanium forming tool threaded to attach to a horn. Tips are commonly used in staking and spot welding assembly methods.
Resin	See Polymer.
Resin Grade	Refers to the classification of the physical and chemical properties of a resin.
Scan Welding	A continuous, high-speed ultrasonic assembly technique used when at least one of the parts to be joined is perfectly flat.
Semi-crystalline Plastic	A plastic with an orderly, repeated molecular structure.
Servo Welder	A welder whose thruster action is precisely controlled through an electrically driven servo motor.
Shear Joint	A joint design formed by the controlled, telescoping melt of two contacting surfaces. A certain amount of interference must be designed into one of the mating parts to accomplish the weld.
Sound	Mechanical, radiant energy (vibrations) that is transmitted by longitudinal waves in a material medium, such as air, water, or metal.
Spot Welding	An ultrasonic assembly technique where two thermoplastic components are joined at localized points. (The components are typically cast or extruded.)

Staking	An ultrasonic assembly technique by which a plastic stud is formed into a rivet head to capture another part, which may be of a dissimilar material.
Stud	The plastic protrusion that is shaped into a rivet head to attach two parts together during staking.
Swaging	An ultrasonic assembly technique by which a ring or a ridge of plastic is formed by the horn face to capture another part.
Thermoplastic	A polymer/resin that can be repeatedly softened, melted, or reformed, making it ideally suited for the ultrasonic assembly process.
Thermoset	A polymer/resin that undergoes an irreversible change during the polymerization process. It cannot be resoftened or reformed, and so is not suited to the ultrasonic assembly process.
Thruster	A pneumatic or servo driven device serving the same function as a press. A thruster can be mounted in a smaller area or otherwise non-standard position. (See also Press.)
Titanium	A high-strength metal alloy with good acoustic properties used in the manufacture of horns and boosters.
Transducer	A piezoelectric device that converts high-frequency electrical energy into high-frequency mechanical vibrations.
Tuning	The process of matching the output frquency of the generator to the resonant frequency of the transducer-booster-horn assembly.