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HIGH FREQUENCY WELDING

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1.0 INTRODUCTION

Heat Sealing, of which High Frequency Welding provides one method, involves the combination of two or more layers of soft thermo plastic material. The majority of products, the manufacture of which involves Heat Sealing lie primarily in the textile field.

Some examples are -----

INDUSTRY	APPLICATION
Automotive Vehicle	Door Trims, Seat Covers, Sunvisors, Carpet Welding
Stationary	Book-binding, Transparent Envelopes, Bank-book Covers, Desk Pads, Wallets
Garment	Rainwear, Baby Pants, Yachting Gear, Waders, Belts, Buckles
Packaging	Blister Packs, Sachets
Footwear	Embossing, Overshoes, Welding uppers to soles
Medical	Drip-feed Bags, Plasma Bags, Urine-bags, Air Splints, Air Mattresses
Furniture	Quilting, Embossing, Seat Covers
Leisure	Swim Pool Covers and Biners, Outdoor Furniture, Inflatable Mattresses, Toys, Luggage, Water Beds
Industrial	Tarpaulins, Bulker Bags, Awnings, Electroplating Liners, Dunnage Pillows
Building	Tension Structures, Airdomes, Caravan Annexes
Agricultural	Dam Liners, Tank Liners, Greenhouses
Military	Inflatable Boats, Inflatable Bridges, Life Jackets, Aircraft Escape Chutes, Inflatable Jacks, Radioactive Protective Suits, Radioactive Disposable Pouches
Civic	Reservoir Liners, Reservoir Covers

The increasing market for plastic has resulted in decreased cost, which has led to a further increase in demand. This has created an economic spiral leading to new uses for these versatile materials for a wide variety of items.

The increasing popularity of plastics has resulted in the need for soft ductile and semi-ductile colorful plastics for clothing products on the one hand. On the other hand it has led to woven-based reinforced plastics with physical specifications to compete with metals, in the building field.

Initially all techniques used in Heat Sealing were of the Thermal type. A hot wire, hot knife or hot bar were used with limited results.

As the industry grew, and as plastics dropped in price, automation of machinery began. The process has now reached such levels that automatic machines make plastic bags at the rate of 6,000 per hour.

Since many plastic products have to be sealed together or made to adhere to each other, the subject of Heat Sealing is of great importance. Heat Sealing affords an economical means of production at high rates of speed and with the utilization of semi-skilled labour.

2.0 HEAT SEALING

Heat Sealing may be defined as the process of welding selected areas of film together by the use of external and/or internal heat.

Most of the plastic films employed in Heat Sealing are of the Thermal Plastic variety, since welding is usually performed when the product is being assembled rather than when the plastic is being manufactured. Heat Sealing is used to selectively weld portions of the surface of the material.
Among the films which can be fabricated by Heat Sealing methods are - Acrylic, Cellulose Acetate Butyrate, Cellophane, Nylon, Polyethylene, Polypropylene, Polychlorotrifluoroethylene, Polystyrene, Polycarbonate, P.V.C., Polyvinyl Alcohol, Polyurethene.

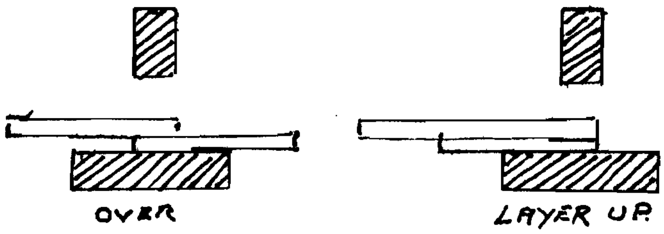
It is important to understand the relationship between Heat and Temperature. The heat sealing process can utilize heated applicators which are at a high temperature compared to the melting point of the film to be sealed. The applicator must retain its heat in order to maintain the proper operating temperature.
Heat may be defined as the product of the temperature and the specific heat of a material and its mass. Temperature on the other hand is merely the thermal state of a material. It is for this reason that a stream of petrol, if admitted directly to an automobile cylinder head would not be ignited by the spark. There is not enough stored heat in the spark to raise the temperature of the petrol to the ignition point. On the other hand the same spark will quickly ignite the petrol air vapour provided by the carburetor.
It is apparent that the thermally heated applicator must have the ability to be heated at the surface contacting the material to be sealed to a temperature required for sealing, based on normal operating speeds. The applicator must have sufficient thermal conductivity to the heating source to overcome the heat absorbed by the welding material at the rates required.
When a plastic becomes liquid due to any form of heating, it will tend to flow away from areas under mechanical pressure, and upon being exposed to cool air it will chill and set. This extruded portion of plastic is referred to as a

bead. Some films such as P.V.C. require substantial beading to ensure a good weld, whereas cellophane requires virtually none.

For thick sections of plastic, post-seal cooling is required. The cooling effect keeps the surfaces fused together from separating immediately after the welding cycle. The cool cycle time need not be long, because it is only necessary to lower the temperature of the plastic in the sealed area below the molten state. Immediate handling after the cooling period can be achieved. Crisp, uniform, well-defined seams are then obtained without bubbles or wrinkles.

2.1 Lap Seal

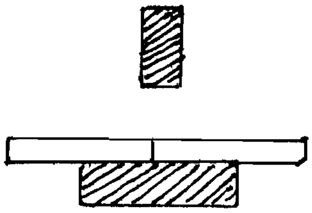
The lap seal is made up of two layers of film overlapping slightly where the seal can be within the area of juxtaposition or extending beyond on one or both sides. This type of seal joins together two wide sheets of film, where the ultimate in strength is required, and where appearance is not important. This seal can be achieved by any method of heat sealing.



LAP SEALS.

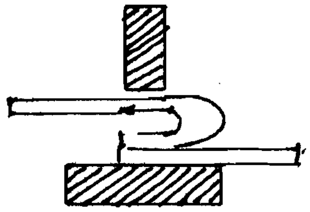
2.2 Butt Seal

The butt seal is obtained when two layers of film do not overlap, and is created by pushing the edges of the two films together. This is the weakest type of seal, since a depression at the butt is less thick than other points in the film. It is also difficult to obtain, because of the problem of properly locating the edges of the film. This seal can also be obtained by all methods of sealing.


BUTT SEAL.

2.3 Fold-over Seal

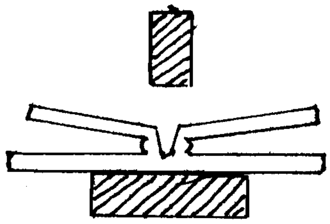
The fold-over seal is useful in waterproofing fabric-supported plastics at the weld line. The strength of such a seal is high. Sewing is usual as a pre-assembly step before the heat sealing. The most common use of this seal is in outer wear and in convertible tops for automobiles. It is predominantly obtained by using thermal heat sealing and dielectric heat sealing methods.



FOLD OVER SEAL.

2.4 Tear Seal

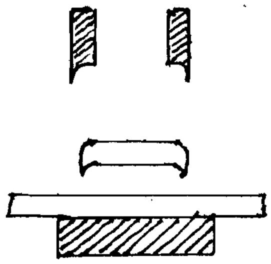
A tear seal deeply penetrates the thickness of the plastic film, in order to readily allow separation between the sides of the sealed area. The die face is sharper than in other areas at the point of the tear seal and is usually at a different elevation. It is impossible to use tear seals on plastic which has been combined with fabrics, though recent developments permit the tearing of plasticized nonwoven fabrics when sandwiched between additional plastic layers. Tear seals are most readily accomplished with dielectric heat sealing methods.



TEAR SEAL.

2.5 Applique Seals

The applique seal or surface tear seal can be achieved by welding two layers of plastic together. One of these layers is torn away selectively from the other, leaving the base layer intact, with portions of the upper layers sealed to it. Applique sealing can be utilized with fabrics as the base material. Zippers for handbags are fastened to a plastic body and the area of the teeth of the zipper is exposed by the waste portion of the surface seal.



APPLIQUE SEAL.

3.0 HEAT SEALING METHODS

It has been shown that Heat Sealing involves the use of internal and/or external heat and pressure to bond layers of materials together in selected areas. Force is exerted to the dies during the heating cycle and can be applied after the heating cycle to effect cooling.

Thermal heat sealing is the method in which the die is warm at all times, precluding the possibility of post seal cooling. Thermal sealing is therefore generally inadequate for thick film sections. Hot air sealing is another method of thermal heat sealing, as is hot wedge sealing. These will be dealt with in detail in the paper to following immediately today.

Thermal Impulse is a more suitable method which employs heating and cooling under pressure. Here a low inertia thermal element is brought up to the desired temperature for a controlled period of time, and then while the work is still under pressure, allowed to cool. This technique is suitable for thin films and usually employed in straight lines or in open moderate curves unconnected to other die segments.

High Frequency sometimes known as dielectric welding is a method for heating a material from within, by electrical loss characteristics of the work when in the presence of a very high frequency alternative current field. It is possible to obtain post cooling since the dies employed operate below the melting temperature of the film. This method cannot be used on all types of thermoplastic films, since the film must exhibit specific electrical characteristics.

Ultrasonic welding utilizes mechanical vibrations to bring about interaction of the molecules of the two films, by means of a vibratory anvil or tool at one face and a stationary plate at the other. Welds are limited at present to short bars or points with substantial power inputs. Seals can be made in most plastics, deteriorating in effectiveness as the film thickness increases.

CHARACTERISTICS OF VARIOUS SEALING METHODS

	THERMAL	IMPULSE	DIELECTRIC	ULTRASONIC
Continuous seals	No	Modified	Yes	Yes
Intermittent seals	Yes	Yes	Yes	Yes
Work loss characteristic	Unimportant	Unimportant	Unimportant	Unimportant
Work thickness range	Moderate	Thin	All	Thin
Machine cost	Low	Low	Moderate	High
Cycle Time	Long	Moderate	Short	Moderate
Usage	Moderate	Wide	Wide	Some
Product repeatability	Excellent	Excellent	Excellent	Fair
Radiation	None	None	Yes	None
Set-up time	Long	Short	Short	Moderate
Warm-up time	Long	Short	Short	Short
Tear seals	Yes	No	Yes	Yes
Textured dies	Poor	Poor	Yes	No
Stepped dies	No	No	Yes	No
Long dies	Moderate	Very long	Very long	Very short
Large dies	Low	Low	Low	Small
Cost of dies	Low	Low	Low	High
Life of dies	Great	Moderate	Great	Short
Maintenance costs	Low	Low	Moderate	Moderate
Operator's skill required	Low	Moderate	Low	Moderate
Combination of different materials	Some	Some	Some	Some

The machinery used to make seals can be broadly characterised as intermittent sealing devices, continuous sealing applicators or modified intermittent continuous sealers.

The choice of method to be used is largely dependant upon the film to be sealed, the type of seal desired and the machinery available.

4.0 HIGH FREQUENCY VERSUS CONVENTIONAL WELDING SYSTEMS

In order to appreciate fully the inherent advantages of high frequency welding, a comparison with traditional heating techniques may be of interest. With conventional heating methods thermal energy is generated externally to the product, and is then transferred to it by conduction, convention or radiation.

The essential feature of the conventional heating techniques is their reliance upon a heat energy transfer from an external source to the surface of the material, and then a somewhat slower transfer from the surface to the interior.

The rate of heat transfer is dependant upon the temperature gradient developed in the material. So, we see that in many industrial processes, conventional heating methods could present a number of serious limitations, including material surface damage through over-heating and extremely slow heat transfer rates through thicker materials. (Remember that dielectric materials are good thermal insulators.)

High frequency welding can overcome these difficulties, so let us now look at some of the advantages of dielectric welding.

5.0 HIGH FREQUENCY WELDING ADVANTAGES

5.1 Uniformity of Heat

An object of uniform section and composition can be raised evenly to temperature. This is obviously advantageous when the material is thick and is a poor conductor of heat.

5.2 Fast Heating Rates

Because all parts of the product are heated simultaneously throughout, progress times can be minimised.

5.3 Ease of Control

The amount of heat generated in the work is predictable. Power input and heating time can be easily controlled electronically.

5.4 Energy Saving

Production can start almost immediately after switching the equipment on. Also little power is used when the applicator is unloaded or on standby.

5.5 Flexibility and Compactness

Flexibility of layout makes it possible to intergrate dielectric heating equipment into the production line. The equipment is compact in relation to alternative systems.

5.6 Improved Working Environment

A more congenial working environment is achieved through reduction of heat leakages normally associated with thermal systems. Also there is no noise or other forms of pollution.

All of the above features of dielectric welding are important. Benefits invariably lead to increased productivity.

6.0 HIGH FREQUENCY WELDING THEORY

High frequency welding (dielctric) materials exhibit two types of polarisation. In the first type, called distortion polarisation, the induced field creates a distortion of the electrons, known as electronic polarisation, or a displacement of the atomic nuclei, called atomic plarisation. This type of polarisation is temperature independant and therefore the overall dielectric constant is the same.

The second type, orientation polarisation, is due to the permanent dipoles obtained with various chemical configurations, and is temperature dependant.

Dilectric materials are usually poor electrical and thermal conductors, and are very difficult to heat using conventional techniques.

Dielectric heating can be used on any non-electrical conducting material with a di-polar molecular structure i.e. one in which one end of the molecule has a positive charge, and the other end has a negative charge. Some plastic materials notably P.V.C. exhibit this property.

During normal conditions, material molecules are at random orientation. When placed in an electrical field however, rapid changes in molecular alignment generate heat.

Let me explain what we mean by high frequency. The flow of electricity in our power grid changes direction 50 times per second and is said to have a frequency of 50 Hertz (cycles per second) i.e. If we could watch current flow in a wire, we would see it go from left to right for 1/100 seconds, then from right to left for 1/100 seconds.

The radio power emitted by a broadcasting station is also an alternating current (A.C.) nature, but it has a frequency of several thousands or millions of Hertz (i.e. changes of direction per second). Similarly dielectric heating is carried out with alternative frequencies, which are of the same order as those used in radio broadcasting.

The frequencies allocated by International Agreement for industrial use in industrial use in dielectric heating installations are -

13.5 MHz)
27.12 MHz) - Radio frequency range
40.68 Mhz)

The Telecommunication Department is the governing Australian authority on radio frequency allocations. Selection of these specific frequencies avoids interference to communication bands.

7.0 HIGH FREQUENCY GENERATORS

Because the frequency has to be higher than the mains (50 Hz) it is necessary to provide a high frequency generator.

The heart of the system is the oscillator, which can be a valve or sometimes a solid state device. The required frequency of oscillation is determined by an inductance - capitance type of circuit, generally known as a tank circuit.

The oscillator can only operate if it has a high direct voltage input. To achieve this, we must connect a step - up transformer and a rectifier in the input power circuit to the oscillator.

In order to transfer the maximum power from the generator to the work, the load must be matched or turned to the same frequency as the generator. This process can be compared to receiving a programme on a radio set. In this instance the transmitting station is sending radio waves at a particular frequency, and when the receiver is tuned to the same frequency, it picks up the radio station.
To tune a radio receiver to a particular station, its tuner inductance/capacitance product (known as the L.C. product) has to be the same as that of the transmitter.

The same applies to the high frequency welder system, where the product has to absorb the frequency produced by the generator.

8.0 HIGH FREQUENCY MACHINES AND TOOLS

The scope of high frequency machines employed in the art is wide and permit a variety of operations to be performed. Most of the machines are of the type known as bed and die, and are plano- parallel as illustrated in the chart below and efforts have been made to use sealing electrodes in the form of wheels. The conventional technique has the advantage of exact reproductibility, as compared to the wheel or continuous sealing method, where the same item is reproduced continuously. Unfortunately the wheel method shown on the chart is unsatisfactory for thicker sections of film because no pre-heating or post seal cooling can be effected and speed is thus limited.

Fig. C illustrates the possibility of sealing films No.2 and No.3 together without involving film No.1. Under the left portion of the press film No.1 has been introduced through a slot in the upper plate and the sealing is accomplished for the three films. In this case the electrode is mounted in the reverse position and sealing is accomplished against the upper platen.

Fig. D illustrates a floating plate method. Here the upper film - beneath the upper die, and the lower film - above the upper die, and the two U-shaped sections of work are all sealed together simultaneously with one generator.

Fig. E illustrates how the capacity of a generator can be increased effectively in such a way as to seal extremely large areas or sections without removing the work from the press. The work is laid down on a slip plate which mounted upon the bed. The die seals only those portions on the slip plate so that most of the upper and lower die sections are sealed as illustrated. When the slip plate is rotated 90 degrees the left and right sections are under different portions of the die. During the second cycle the die will select only those portions which lie over the slip plate. This method can be used for side to side or front to back registration or in the rotary method as illustrated.

Fig. 8 F illustrates another slip-plate technique using the tapered method. The work is laid on a tapered wedge of metal and a plain bar is dropped on this wedge. The seal takes place only on that portion of the slip-plate outlined by the die.
It is sometimes advantageous to seal the dielectric work into a tube as illustrated in Fig. 8 G.

9.0 ELECTRODE DESIGNS

In order to deliver high frequency power from a generator to the product, a large number of electrode configurations has been devised to suit various applications.

HIGH FREQUENCY MACHINES AND TOOLS

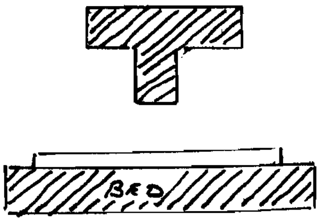


FIG A

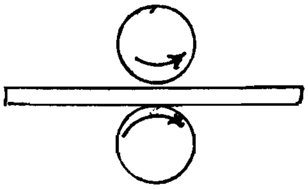


FIG B

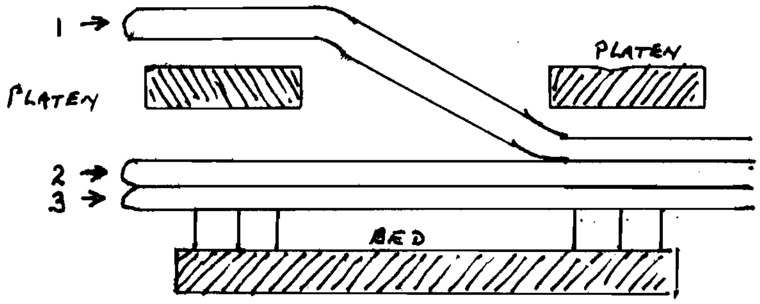


FIGURE. C.

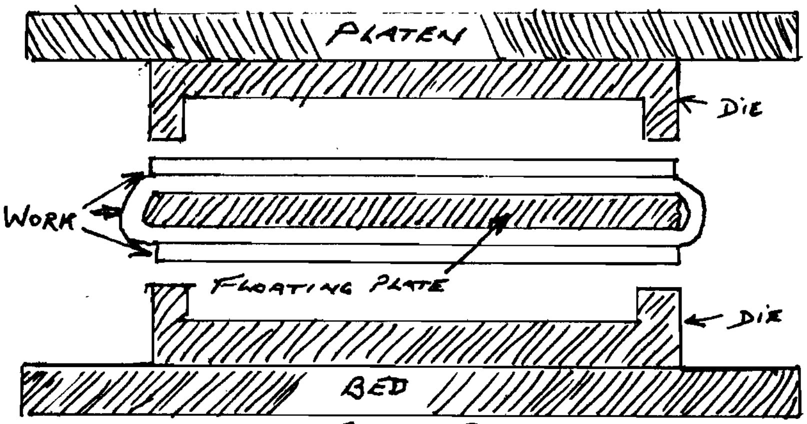


FIGURE D

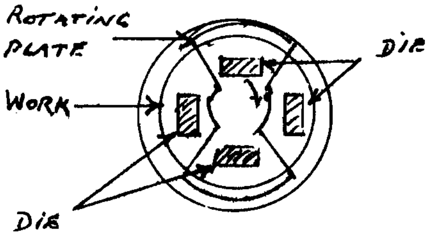


FIG. E.

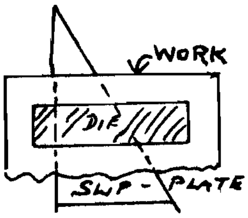


FIG. F

Dielectric sealing methods including the convential bar, rotary wheel, over under plates, floating plates, rotary slip plates and tapered slip plates techniques.

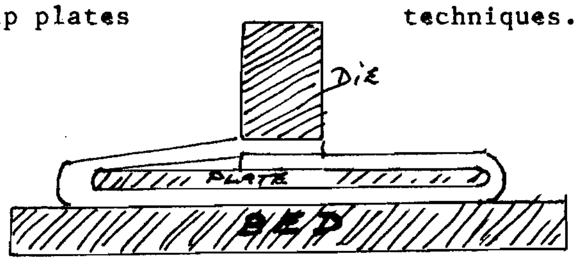


FIG 8G

Electrodes should be positioned as close as practicable to the high frequency generators to minimise inductance and stray radiation in the inter-connecting power leads.

Either brass or aluminium electrodes may be used. Strips or plates of widths ranging from 0.5 to 25mm are generally used, depending on the shape size the mechanical load to be expected, and the nature of the work.

10.0 REGULATIONS

In considering high frequency equipment, one must be familiar with the following regulations.

Wiring Regulations (AS 300 - 1976 and AS 2065 - 1977).
Screening of generator or electrodes (to minimizr stray radiation effects on the operator).

11.0 ECONOMIC CONSIDERATIONS

Let us now look at the economic considerations associated with high frequency welding.

High frequency welding invariably achieves -
an increase in production without extra labour
Unskilled operators can be utilized
Improvement in product quality
Reduces bottlenecks in production (due to in-line configuration or equipment)

The following factors should be looked at -
Equipment cost
Investment allowance
Equipment depreciation
Maintenance
Quality Control cost saving

Analysing the economics of high frequency welding, the following figures can be used as a guide -

1 kilowatt of high frequency power would product a 25 square centimetre weld within a 3 second weld cycle.
Weld dies cost approx. $1.5/linear centimetre
Machine rating, range from ½kw to 120kw output
Equivalent cost about $1,000 per kilowatt input
Equipment efficiency about 70%
Stand by power consumption about 10% input power
Component replacement and maintenance about 2% per annum.

12.0 ACKNOWLEDGEMENTS

I would like to express thanks for the assistance of Siedensha Australia Pty. Ltd. in the preparation of sections of this paper.

13.0 REFERENCES

1. Anon, Modern Plastics 40, No.5, 84 (1963).