

**HIGH FREQUENCY  
WELDING**

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**HANDBOOK**

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**FHFV**

**FEDERATION OF HIGH FREQUENCY WELDERS**

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## PREFACE

This handbook is produced by the Federation of High Frequency Welders to describe all aspects of high frequency welding. Its aim is to describe the process of High Frequency Welding without delving too far into technical details.

Because of the wide variety of High Frequency welding machines installed throughout FHFV member's premises, descriptions of machines will be limited to the types commonly met.

If you come across a name or phrase you don't understand, please check the Glossary at the back of the handbook.

The management committee would like to take this opportunity to thank everyone who contributed to the production of this handbook. Specific acknowledgement is due to the following:

Charles Hughes of Radyne Ltd for the set up and weld fault finding flow charts.

Cliff Bennion for 'Back to square one in the U.K' in Appendix A.

Tony Cooper of Weston Vinyls for the sub-sections in Section 7 dealing with 'The Role of Plasticiser in Flexible PVC Sheeting', 'Cold Crack Problems with Stationery Products', 'Colour Matching of Flexible PVC Sheeting' and 'The Importance of Uniform Gauge in Calendered PVC Sheeting'.

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## HEALTH & SAFETY

### GENERAL

It is not within the scope of this handbook to give detailed information about Health and Safety. However, before working in a plastics processing factory production personnel should be aware of the work hazards involved. This information is available in general terms from the Health and Safety at Work Act of 1974 and should be supplemented by company-specific information relevant to the hazards present in a particular factory.

Everyone in a company has a legal responsibility to meet the requirements of the Health and Safety at Work Act. The company management has a duty to establish and maintain safe working conditions. It is their responsibility to make the factory a safe place to work in and ensure that everyone understands and obeys the safety rules, instructions and codes of practice.

It is an employee's duty to make sure that he/she fully understands the safety rules and procedures and then to carry them out. Never hesitate to ask for more information and fuller explanations.

The Safety at Work Act also requires employers to have a written safety policy, which spells out its policy on health and safety matters, and the organisation and arrangements for implementing the policy. This written safety policy should be read and understood by all employees.

### HF WELDING HAZARDS

The following paragraphs give warnings about the potential hazards involved when operating, setting or maintaining HF Welding equipment. These warnings cannot be comprehensive enough to cover every potential hazard in every plastics factory. Always ensure that local safety rules are understood and obeyed.

Personnel responsible for First Aid must be able to provide treatment for all potential injuries including RF burns.

One hazard that requires special emphasis is that encountered with guillotines. These machines are installed throughout the stationery sector of the of the plastics industry and can cause serious injuries if misused or are poorly maintained. They are covered by an Approved Code of Practice (ACOP) which requires the following checks on their electronic eye guards:

- (a) Daily            Operation must be checked by maintenance personnel.
- (b) 6-monthly      A speed check must be carried out by an approved engineer and a certificate issued.

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HAZARDS	WHAT YOU SHOULD OR SHOULD NOT DO
<p><b>Fire</b></p> <p>Fire is especially hazardous in thermoplastics processing as the thermoplastics themselves are basically hydrocarbons, which will melt and degrade if sufficiently hot, to produce dense choking fumes, which may cause death by asphyxiation even if the fire is contained.</p>	<p>(A) ENSURE THAT YOU KNOW YOUR LOCAL FIRE DRILL.</p> <p>(B) BE ALERT TO THE POSSIBILITY OF FIRE AND OBEY THE 'NO SMOKING' RULES.</p>
<p><b>Electrical</b></p> <p>Machines use voltages high enough to cause injury or death. Even when the electrical power supply is isolated, electrical energy at dangerous levels can be stored by capacitors and may still be present.</p>	<p>(A) NEVER TOUCH ANY OF A MACHINE'S ELECTRICAL COMPONENTS UNLESS YOU HAVE BEEN TRAINED TO DO SO.</p> <p>(B) DO NOT REMOVE ANY COVERS OR PANELS FROM ELECTRICAL CIRCUITS UNLESS:</p> <p style="padding-left: 40px;">(i) THE RELEVANT ELECTRICAL ISOLATOR(S) HAVE BEEN LOCKED OFF AS REQUIRED BY SECTION 12 OF THE ELECTRICITY AT WORK REGULATIONS.</p> <p style="padding-left: 40px;">(ii) ANY STORED ENERGY HAS BEEN DISSIPATED OR DISCHARGED TO EARTH.</p> <p>(C) KNOW THE LOCATION OF EMERGENCY OFF PUSHBUTTONS AND HOW TO USE THEM.</p>

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HAZARDS	WHAT YOU SHOULD OR SHOULD NOT DO
<p><b>Electromagnetic Radiation</b></p> <p>Welding machine generators produce High Frequency electromagnetic radiation. This radiation can have a field strength strong enough to cause injury if not properly shielded.</p> <p>The electromagnetic radiation can also induce currents into metal objects within close proximity to electrodes, causing them to rapidly heat up.</p>	<p>(A) DO NOT APPROACH LIVE UNSHIELDED ELECTRODES UNLESS YOU KNOW THAT THE FIELD STRENGTH IS WITHIN SAFE LIMITS. IF IN ANY DOUBT, CONSULT YOUR SUPERVISOR.</p> <p>(B) DO NOT WEAR JEWELLERY, E.G. RINGS, BRACELETS OR WATCHES WHEN WORKING CLOSE TO LIVE ELECTRODES.</p>
<p><b>High Temperature</b></p> <p>Some components run at a temperature high enough to cause severe burns.</p>	<p>(A) DO NOT TOUCH HOT COMPONENTS WITH YOUR BARE HANDS. IF IN DOUBT WEAR SUITABLE GLOVES.</p>
<p><b>Gas</b></p> <p>Some gases produced during the HF welding process, and cleaning fluid vapour may be toxic, corrosive, carcinogenic or flammable. They may also cause asphyxiation through oxygen deprivation.</p>	<p>(A) ENSURE THAT THE WORK AREA IS WELL VENTILATED AND TAKE THE NECESSARY SAFETY PRECAUTIONS AS DETAILED IN LOCAL REGULATIONS.</p> <p>(B) ENSURE THAT SAFETY INSTRUCTIONS SUPPLIED WITH MATERIALS AND FLUIDS ARE UNDERSTOOD AND OBEYED.</p>
<p><b>Chemicals</b></p> <p>Some chemicals used in the plastics industry are toxic and can leave toxic residues.</p>	<p>(A) ENSURE THAT SAFETY INSTRUCTIONS SUPPLIED WITH CHEMICALS ARE UNDERSTOOD AND OBEYED.</p>

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<b>HAZARDS</b>	<b>WHAT YOU SHOULD OR SHOULD NOT DO</b>
<p><b>Compressed Air</b></p> <p>Compressed air can enter the body through the skin and cause serious injury.</p> <p>Pneumatically operated components can be actuated suddenly, even when the equipment is not operating, causing serious injury.</p>	<p>(A) ALWAYS FOLLOW THE PROCEDURES FOR USING AIR LINES DETAILED IN LOCAL REGULATIONS.</p> <p>(B) BEFORE WORKING ON OR NEAR PNEUMATICALLY OPERATED EQUIPMENT, ENSURE THAT THE HIGH PRESSURE AIR HAS BEEN EVACUATED FROM THE CIRCUIT.</p>
<p><b>Mechanical</b></p> <p>Injury can be caused by heavy components, sprung components and machinery in motion.</p>	<p>(A) DO NOT TRY TO LIFT HEAVY ITEMS WITHOUT THE APPROPRIATE LIFTING EQUIPMENT.</p> <p>(B) TAKE CARE WHEN MOVING HEAVY COMPONENTS. ENSURE THAT THEY REMAIN STABLE TO AVOID ANY RISK OF TOPPLING.</p> <p>(C) HANDLE SPRUNG COMPONENTS UNDER COMPRESSION OR TENSION CAREFULLY, TAKE SUITABLE PRECAUTIONS, INCLUDING EYE PROTECTION, BEFORE MAINTAINING SMALL SPRUNG ITEMS.</p> <p>(D) BEWARE OF MACHINERY IN MOTION SUCH AS GUILLOTINES, ROBOTIC ARMS, CONVEYOR BELTS, PRESSES AND HANDLING MECHANISMS. REMEMBER THAT MACHINERY CAN START SUDDENLY. ENSURE THAT ALL SAFETY GUARDS ARE CORRECTLY FITTED BEFORE USE.</p>

## 1. INTRODUCTION

This section introduces HF welding and the products made, briefly describes the history of HF welding and also describes the formation of the Federation of High Frequency Welders.

### 1.1 WHAT IS HIGH FREQUENCY WELDING?

High Frequency Welding is the process of fusing materials together by applying high frequency energy to the area to be joined. The energy produces localised heating of the materials, causing them to soften and melt, thus allowing their molecules to intermingle. After a period of cooling, the materials become joined together at the point of the weld. The resulting weld can be as strong as the original workpiece materials.

The most widely used material in High Frequency (HF) welding is Polyvinyl Chloride (PVC) sometimes known as vinyl. It is important to note that not all thin, flexible thermoplastics can be HF welded; the suitability of a plastic for HF welding is determined by its molecular construction. For example, polyethylene sheeting is not suitable whereas nylon 66 although difficult to tear seal can be welded.

As with any form of welding, the materials must be heated to a high enough temperature to cause them to fuse with each other. In HF welding, the workpieces are also pressed together to help them fuse.

There are two main types of HF Welding:

- (a) Plain Welding      The welding of two or more thicknesses of material, the welding tool can be engraved to give the welded area a decorative appearance.
  
- (b) Tear-Seal Welding      The dual process of simultaneously welding and cutting a material. This is achieved by incorporating a cutting edge adjacent to the welding edge. This compresses the hot PVC enough to allow the scrap material to be torn off. This technique can also be used to provide 'cut outs' to enable plastic packaging to be hung on sale displays.

The welding process can incorporate 'blind' embossing which places lettering, logos or decorative effects onto the welded items.

Another technique used is Appliqué Welding where a piece of material is cut out and welded to the surface of another to provide an ornamental effect.

## 1.2 TYPICAL END PRODUCTS

A wide range of products can be manufactured using HF welding. The range of products is increasing as new applications are discovered. A few examples are listed below:

Stationery	Book covers, labels, binders, notebooks, stationery wallets, zip bags and office files.
Inflatable Items	Advertising novelties, beach balls, toys, air/water beds, rafts, and life jackets.
Household Items	Chair upholstery, headboards, quilting and table mats.
Everyday Items	Badges, car door panels, signs, tents, umbrellas, chequebook covers.
Large Items	Tarpaulins, tents and marquees, pool liners and lorry covers.
Medical Items	Colostomy bags and blood bags.

In order to produce these different items as efficiently and economically as possible, the range of HF welding equipment available is expanding.

## 1.3 HISTORY

The origin of HF welding is closely associated with the early days of radio and radar when the heating effect of radio waves was discovered. Since then, the development of thermoplastic materials and HF welding have progressed hand-in-hand, enabling new materials and the machines necessary to weld them to be manufactured.

The history of HF welding since its origin is given in an article written by Cliff Bennion, an honorary member of the Federation of High Frequency Welders. The text of the article is reproduced in Appendix A of this manual.

## 1.4 THE FEDERATION OF HIGH FREQUENCY WELDERS

In late 1986, a group of HF welders arranged a meeting to discuss forming an organisation to represent the interests of all HF welders in the UK. After much discussion they decided to contact the several hundred companies that make up the HF welding industry in the UK. As a result of this initial meeting, another meeting was held in mid-1987, when a Management Committee was elected, and the Federation of High Frequency Welders (FHFV) was formed.

Within a year of the formation of the FHFV, 130 companies had joined the Federation. In 1988, the FHFV became a company limited by guarantee. Since its formation in 1987, the Federation has gone from strength to strength, now having members world-wide.

The FHFV is dedicated to the promotion and well-being of manufactures, and their suppliers in the High Frequency Welding industry. Based in Ashburton, Devon, the Federation is non-profit making and non-political and exists solely for the benefit of its members.

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The Federation offers a wide range of services and benefits to its membership including technical, commercial and legal advice.

The High Frequency Welder, a glossy bi-monthly magazine produced by the Federation, is the mouthpiece of the industry and provides the forum for discussion within the industry. The magazine reaches a wide readership, mainly within the U.K., but also throughout the E.C. and in many other countries across the world.

## APPENDIX A

### A VIEW BACK TO SQUARE ONE IN THE U.K.<sup>1</sup>

Recognised since the middle of the century as a unique industrial process, HF welding has no recognised inventor. Some ways and means of melting PVC by high frequency electricity seem to have evolved in World War II when PVC became a useful substitute for rubber. It might have happened sooner but calendered PVC was virtually unknown when reliable sources of HF power were devised by the radio industry as short wave broadcasting expanded between the wars. Among the noticeable side effects of a radio transmitter's power were objectionable heating of materials in and around the transmitting equipment and annoying reflections of radiated energy from distant objects which interfered with reception.

Radio echoes were soon put to good use in the first cumbersome radar, but the exploitation of dielectric heating effects is not so well documented. HF generators were certainly used prior to 1939 in medical diathermy equipment for it is reported that some of these were subsequently fitted with antennae to jam German radio signals guiding bombers to English cities. It therefore seems likely that the first 'marketed' application of HF heating was for the intentional warming of live human flesh. Now we have guidelines and legislation to avoid it in an HF welding workplace.

The most famous industrial applications of dielectric heating in the pressure of war appears to be the heating and rapid curing of synthetic resin glues in wooden propellers and aircraft such as the Mosquito. These techniques were ready to be applied in post-war production of furniture and TV cabinets, but very little prior art existed for welding the first calendered PVC which arrived in quantity, with all sorts of claims for its properties. It truly was a wonder material which could imitate expensive fabrics and almost anything else, appearance-wise. Its disadvantage was that sewn seams were not very strong, or waterproof like the fabric itself.

Vinyl sheeting is thermoplastic so heat sealing was the obvious answer, and better still if the heat is created inside the material instead of melting the outside before it gets to where it is needed. HF equipment manufacturers knew

more than anyone else about this trick and had set about meeting this new need. Two U.K. prototype pedal welders have been dated at 1945 and 1946. But although heating a dielectric in an HF field between electrodes was already a successful manageable process for drying and softening plastic pellets for compression moulding actually pressing electrodes against much thinner plastic and producing more intense heating than ever needed previously was a much tougher proposition.

Intense electric stress destroys insulation where it is too fierce and causes flashovers and damaging arcs. With hindsight it is easy to see that the first commercial success of early, pedal operated, welding machines would naturally be in welding the thickest useful materials. These included varieties of PVC coated cloth, rapidly replacing traditional weatherproofed fabrics. Unlike calendered sheeting, cloth supported vinyl material maintained vital thickness even when the welding process was inadvertently overdone, so there was far less danger from accidental flashing between welding tools. These were not elaborate, usually consisting of little more than matched pairs of straight brass bars, seldom longer than 150mm or wider than 10mm. Fishermen's 'oilskins', motorcyclist's clothing and tarpaulins were early beneficiaries of the new process. The cleverly cut shapes of clothing were necessarily sewn together before the seams were sealed on a welding machine, and ex-sewing machine operators soon learned that stationary piece of brass became as unfriendly to stray fingers as a vibrating needle when it became a live electrode during welding.

By popular request the next models of welding machines inverted the connections to the HF generators so that the upper welding tool then became the 'live' electrode, 'the better to see the devil you know'. The now earthy lower electrode could then be safely enlarged into a useful flat workplate. But the task of welding thin sheeting remained hazardous until it was appreciated that facing the cold plate with a sheet of inert insulating material reduces power required to combat heat losses and provides extra insulation between electrodes, which

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<sup>1</sup> Written by Cliff Bennion - Honorary Member of the Federation of High Frequency Welders

becomes more important as the welded plastic gets thinner.

The beneficial use of this buffer sheet in plain welding inevitably led many people to the 'discovery' of tear-seal welding when material in welds pressed thin enough to lose strength still provided seals between material on each side of the 'spoiled' weld which were usefully strong. Here was a way to cut parts to shape and weld them together in one go! It was undeniable that resulting products looked much better when the severed edges were nicely defined by a sharp edged welding tool but this was technically objectionable because sharp edges intensify electric stress. However, the commercial attractions of the promising tear-seal technique were so strong that this handicap was accepted as a necessary evil. But the flashover menace was now firmly back on the agenda, top of the list of problems to be solved. It remained on the list for another ten years.

The new products which sheeting manufacturers introduced during the 50's were noticeably better, cheaper or different than anything seen before. Some were quite suitable for welding, others were not. Today's HF welders would object to carbon black or metallic powder in the formulation of a sheeting or the ink printed on it: ignorance of such things caused much chagrin then. But the entrepreneurs pressed on, asking silly questions of the 'experts', attempting the impossible and succeeding surprisingly often.

Welding machines were now quite practical devices although best results were obtained by very careful users with good tool repair facilities. They were ready customers for larger machines, needing compressed air to work the presses. Too few knew that high pressure air as delivered into tyres is too wet and dirty to pipe into a welder, but everyone was climbing the learning curve.

Welding toolmaking was progressing rapidly. While traditional engineering toolshops were still bashing and cutting raw metal to new shapes needed for welding, others had seen likeness in the printing process. Printers had enjoyed plenty of time to devise and test the parts they assembled to provide a printing face on the letterpress 'tools' which put ink on paper, and their traditional suppliers were overjoyed to find a new and growing market for the specialised products they could sell virtually off-the-shelf for welding tool construction. Accurately made 'printers' brass rule, bent to shape and fixed on edge to flat aluminium plates enabled all sorts of possibilities to be realised at modest cost, and still does. There is

little difference in the construction of most tools built today and those fabricated in the late 50's.

By then HF welding was penetrating old industries and providing some products which could be made no other way. Sizes ranged from key fobs to air-beds, raincoats and plastic 'quilting'. Little remains of many hundreds of miles of the latter, made with ever thinner PVC sandwiching vinyl foam padding which provided a soft feel and emphasis for its usual 'chicken wire' pattern of overall welding. Changing tastes staved off its threat to cover everything touchable, but we have to thank this product for stimulating development of automatic feeder mechanisms gripping sheeting right off-the-roll and precisely advancing it into place under a welding tool, usually in a bridge type press with 7 kW - 15 kW of HF power.

Meanwhile, rainwear manufacturers struggling with early model welders and demand for ever cheaper garments had welcomed the superbly timed launch of the first product of a new company, dedicated to making welders. This was a new 1.5 kW machine, quite able to cope with 0.1 mm sheeting, the thinnest worth using, which tamed the flashover bugbear primarily because it operated at a higher frequency, - selected according to the customer's area to avoid interfering with regional TV transmissions (see High Frequency Welder Magazine, Issue No. 10 pp. 7). Its electrics were also boldly innovative but out of sight, unlike its ergonomic design and engineered press mechanism, - adjustable to suit tool depth, weight and best welding pressure. It worked like a dream and its effect was sensational. Few customers cared that it might sometime become illegal to weld at those frequencies. The payback time was only a few months when everyone needed a Pakamac (a super brand name used as indiscriminately as Hoover's). Renee Bazin's Acme No. 1 pointed the way pedal welders had to go and both Redifon and Radyne, the two major competitors, responded very smartly with the introduction of remarkably similar models into the ranges they were already selling.

Two earlier émigrés from Redifon's HF Heating division had founded Radio Heaters Ltd. which, under the RADYNE trademark, had grown to become the world's largest makers of industrial electronic heating equipment. In broad terms, C. E. Tibbs looked after the metal heating applications and E. C. Stanley was responsible for dielectrics, including HF welding. Work on every kind of HF welding application occupied a sizeable department which was accumulating a wonderful fund of experience, unexcelled in the 'big-stuff' going into the motor factories to produce car upholstery and trim. It all showed in

Eric Stanley's handbook 'High Frequency Plastic Sheet Welding', published in 1960. Amazingly, many welders refused to buy it, objecting that it could not teach them anything about their particular business, that all Radyne customers should get a copy gratis, or believed it was just an expensive catalogue of that company's products. In fact, its 340 pages in hard covers provided a comprehensive review of theory and current practice both large and small, with diagrams and photographs. Who could blame the author for using his own company's pictures, they were all exemplary, with the text remarkably clear and apparently unbiased. It never ran to a second edition so existing copies are highly prized, our best record of the remarkable progress the state-of-the-art had made in 15 years.

The first double shuttle trays and automatic rotary indexing tables had proved their worth and, with roll-fed linear feed mechanisms, led the way to faster production, for HF welding was now a manageable process with new equipment serviceable enough to last longer than anyone imagined. All the groundwork had now been done for HF welders to prosper in the booming 60's.

Despite the publicity 'radio welding' was getting in the press and exhibitions, most practitioners found themselves in the business seemingly by pure chance, when they learned it was a process which could help in the manufacture of their existing products, or the best way to produce something they had invented 'to be made in sheet plastic'. Sheeting suppliers then recommended a welding equipment manufacturer hopeful that the favour would be returned. This dependency on mutual goodwill was probably the greatest spur to improving the welding quality of PVC sheeting on the premise 'look at the price and feel the width'.

Entrepreneurs who were not intimidated by the capital cost and technology of the heavyweight electronics which make it work discovered a clean fast process capable of converting sheet PVC into first class finished goods with astonishingly low tooling cost. They set about creating new products and, like the lively mac makers, chased the new markets for all they were worth.

Welding machines could sold by the dozen when a new market was developing, but some proved worth far less than others and some never got going, e.g. Nylon (type 6) shirts promised much when found to be weldable: it was not the intending welder's fault that sales of these garments died in ignominy just when deodorant sales were rocketing. Nevertheless

there were plenty of successes, with products that we now take for granted and some that we don't need anymore.

Entire factories have been kept busy on a single new product line. One such was lightweight welded PVC overshoes, popular with both sexes until affluence brought tall boots and motor cars to keep feet dry. Most cars were then sporting welded Vinyl upholstery, attractive, washable and durable', but even so, they prompted substantial sales of clear PVC protective covers to proud new owners. Nowadays few drivers are keen to sit on even a single thickness of impermeable plastic. The market life stories of many welded products is rich material for business case studies.

Talent to perceive and satisfy new needs is not special to the HF welding industry but has certainly given it energy to adapt and grow over the years. Another characteristic is a rugged independent spirit, which probably accounts for the abundance of suppliers to the hundreds of small companies which produce most of the U.K.'s welded products.

The technology of the welding process is just one application of HF dielectric heating, which is closely related to HF induction heating applied to metals. HF power generators for all the processes are much the same except for their operating frequencies, so the engineers who build them know a lot about HF heating in general. Nevertheless, the fascination and prospects for welding were sufficient motivation for the founding of the majority of U.K. welding equipment manufacturing companies, by people who believed they could build a better welder, usually a particular type. If they succeeded they went on to extend their product range to compete on a broader front, not excluding induction heating!

A new type of welding tool was developed in the 60's which enables a stiff sandwich of a variety of materials to be welded and/or bonded together and then, in a succeeding follow-through stroke, cut around the profile by a close fitting knife requiring very high pressure. Cutting presses had been used in leathersgoods and clothing industries for many years and the latest hydraulic models with sophisticated controls were ready and suitable for applying the two stage motions and pressures for this type of tooling. Co-operation between HF and cutting press engineers thus produced a new type of 'cut-weld' machine and added new names to the list of suppliers to the industry.

A completely different type of tooling was developed in the 70's. This separates the top

surface of welded material from the upper heating electrode with a thick membrane of moulded silicone rubber which impresses the workpiece to reproduce decorative details and texture of flat master models with remarkable fidelity. This 'flow-moulding' technique is best exploited using machines built for the purpose, but these were not so radically different from 'ordinary' welders.

Both of these techniques found immediate use in shoe manufacture: flow-moulding of fancy uppers and cut-welding of insoles. Of course new applications for old techniques are discovered all the time, not least in plain and tear-seal welding.

The process at the business edge of ordinary welding tools remains much the same except that tool temperatures are maintained steadier, where possible, in the cause of quality control. The threat of damage from accidental arcing has receded almost out of sight in the face of increasingly successful countermeasures.

When it seemed impossible to prevent occasional arcs the problem resolved into two parts, early detection and damage limitation. Detection methods tested included radios sensitive to the crackle of the tiny lightning striking the arcs. (Engineers were seen listening to miniature war-surplus MRC1 receivers as intently as the French Resistance they were designed for.) Adjustable overload trips worked if an arc caused power to increase: sometimes they didn't. Best results were obtained by using the direct current path through the plasma of an arc between the welding electrodes to operate a relay which opened the HF generators overload trip circuit to cut off its power supply. Such arc-limiters became the norm and were easily fitted to earlier welders, but unwanted damage still occurred in the split second electro-mechanical devices required to operate. Quite fancy electronic gadgetry was needed to 'disable' an HF generator instantly, and it became available in expensive 'bolt-on' goodies.

In 1968/69 a new machine from a new manufacturer again shook up ideas on controlling the arcing menace. Its generator was disabled between each and every heating cycle, by simply preventing its oscillator valve from conducting (which it is very ready to do, at high frequency). The technique is as old as HF wireless telegraphy but was a novelty when applied to plastic welding, requiring only cunning, but relatively inexpensive, extra circuitry to detect an arc and clamp a blocking bias voltage on the oscillator valve's grid electrode somewhat earlier than programmed by the heating timer. The rest, as they say, is

history; it became a 'standard practice' for there is no quicker way to terminate HF power. Today, modern electronics enable unexpected rise and falls of power levels to be detected as well as change in resistance of work material so that detection of imminence can prevent an arc occurring. Arc Anticipators are with us now.

Generators had improved in any case, discarding bulky banks of weirdly luminous rectifier tubes or their soulless alternatives, selenium rectifiers with their stink of protest at old age or misfortune, (which put much strain on interpersonal relationships). Solid state devices have not yet replaced oscillator valves, but even these now hide their lights within sturdy ceramics. No matter, a generator is just a converter of power to heat the plastic where the work is done and both welder users and their suppliers had switched most attention to finding ways of doing it better.

HF welding leaves scope for ingenuity in methods of presenting work for welding and this was seen in the variety of arrangements tested as new products were developed. The most teasing problems concerned the correct positioning of ancillary components necessarily included with work materials which are then welded around them. Gravity could hold substantial board stiffeners in place for welded padded seating and baby carriage panels but was no help in holding rubber bands in baby pants, made in millions, eventually at prices only attainable with special purpose machines. Generally similar problems beset welders tackling the large and diverse markets for book covers. Simple methods of locating their board stiffeners work well enough to be economical for short runs of loose leaf ring binders, but more sophistication is required for more complicated work or high volume production.

European manufacturers with larger markets were first to take serious advantage of special purpose machinery unwinding rolls of PVC and inserting magazine-fed stiffening boards between the webs as they were carried into a welding press. Most other additional operations of printing, stamping, punching, pocket welding and final separation can now be included 'in line'. An automatic production line need not be straight, as rotary indexing tables also have much to offer, possibly allowing most scope for 'pick and place' robotic machines to be stationed where most convenient. We have already reached the point where an automated production line can be assembled from standardised units where the welding station, with appropriate size of press and generator, is just one of those units.

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Nevertheless there is still need for both general purpose and special welding machines for operations which demand special methods. Special methods were needed for producing blood transfusion sets and the subsequent development of markets for HF welded disposable medical products such as colostomy bags has been astounding. The particular demands of these markets not only merit special machinery to manufacture the products but justify dedicated buildings with controlled purified atmospheres to house them. Similar investment by manufacturers of PVC to stringent medical specifications has been correspondingly rewarded. A list of current application of HF welding now includes hundreds of diverse products and continues to grow. It is hard to predict how and where new markets appear but they surely do and this industry has shown itself notably willing to respond to opportunity. Inevitably, this account of seemingly significant events seen by one guy's eyes must miss much that is important to many people engaged in plastic welding. Mergers, acquisitions, takeovers, buy-outs,

disposals, all these things shape our lives and this industry has seen them all, too many to chronicle here even if we knew the facts.

However, there is one significant event in recent history that must be mentioned. In December 1986 a couple of dozen HF welders who believe most luck comes to those who try hardest arranged a meeting which discussed setting up an organisation to represent and advance the interests of all U.K. welders. The consensus of that meeting was that it would meet a real need but much work was needed to enthuse several hundred companies who comprise the industry to support the idea with money and forbearance until the (unpaid) effort entailed could bear fruit. The first tangible result was a much larger meeting in Coventry in June 1987 which endorsed the principle, pledged support, and elected a Management Committee here and then. The rest really is history, now properly recorded in the minutes of meetings of that committee and the magazine of the Federation of High Frequency Welders.

GLOSSARY OF TERMS USED IN THE HF WELDING INDUSTRY

Anode Current	The electrical current flowing from the anode(s) of the generator's output valve(s). This current gives an indication of the output power of the generator and is dependant on the setting of the output power control (usually a variable capacitor) which resonates the generator's output tuned circuit. The current is also dependent on the loading effect of the electrode and tooling on the tuned circuit.
Appliqué Welding	A welding process where a piece of material is cut out and welded to the surface of another to provide an ornamental effect.
Arcing	An electrical "flashover" which occurs if the welding machine's electrodes (i.e. the platen at HF potential and the worktable at zero HF potential) come too close together or touch. Arcing can damage both the generator and the tooling, therefore arcing anticipator circuits are usually incorporated in welding machines to cut off the HF power before damage is caused.
Barrier Material	A thin sheet of dielectric that is placed between the work material and the welding machine's lower platen to reduce heat loss, and in tear-seal welding to prevent damage to the tooling. Any material used as a barrier must be able to be repeatedly used in the electric field without being affected.
Blind Embossing	A technique which can be incorporated into the welding process to place lettering, logos or decorative effects onto the welded items.
Buffer Material	An alternative name for Barrier Material.
Calendered PVC	PVC which has been finished by passing between heated metal which impart the required finish and thickness of the product.
Cooling Time	The time between the end of the Welding Time and the lifting of the tooling from the workpiece.
Dielectric	Any, solid, liquid or gas which can sustain an electric field, hence an insulator. When a thermoplastic material is HF welded, it acts as a dielectric between the electrodes.
Electrode	A conductor through which an electric current enters or leaves an electrolyte. In HF welding, the term electrodes refers to the platen and the worktable. In this case, the electrolyte is the thermoplastic being welded.
Frequency	The rate of repetition of a periodic disturbance, measured in hertz (Hz) (cycles per second). In High Frequency welding, the most commonly used frequency for welding is 27.12 MHz.

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HF	The abbreviation for High Frequency, the range of Radio Frequencies between 3,000 and 30,000 kHz or 3 and 30 MHz.
HF Power Rating	The maximum output power of an HF welding generator, quoted in watts (W) or kilowatts (kW).
High Frequency	The range of Radio Frequencies between 3,000 and 30,000 kHz or 3 and 30 MHz.
Plain Welding	The welding of two or more layers of thermoplastic material by applying HF power to heat and thereby fuse the inner surfaces.
Platen	The upper electrode of a welding machine.
Polyolefins	Fibre of film made from a linear polymer obtained from an olefin especially ethylene (giving polyethylene) or propylene (giving polypropylene).
Power Control	A device, usually a variable resistor or capacitor located in the power output stage of a generator, which enables the HF output level of a welding machine to be adjusted.
Pressure	The force applied to the workpiece materials to compress them during the welding cycle.
PVC	Polyvinyl chloride - The best known and most widely used of the vinyl plastics.
RF	Radio Frequency - The spectrum of frequencies between 10 kHz and 3 GHz. Within this spectrum, frequencies are split into Low Frequency (LF), Medium Frequency (MF), High Frequency (HF), Very High Frequency (VHF) etc. Note that RF is the generic abbreviation for radio frequencies and is sometimes misleadingly used instead of HF.
Stick Weld	A weld where the two surfaces to be joined fail to become perfectly homogenous. The weld often appears to be normal, and a special technique of static loading is necessary to ascertain whether the weld is satisfactory.
Tear-Seal Welding	The dual process of simultaneously welding and cutting a material. This is achieved by incorporating a cutting edge adjacent to the welding edge.
Thermoplastic	Becoming plastic on being heated. Specifically any resin which can be melted by heat and then cooled, the process being repeatable any number of times without appreciable change in properties.

Tuned Circuit	An arrangement of reactive components (inductors and capacitors), connected in series or parallel to offer a low or high impedance respectively, to an alternating current at the resonant frequency. HF generators use a series tuned circuit to match the output of the valve(s) to the impedance of the welding head components. This matching enables the maximum transfer of HF power.
Welding Time	The length of time that the HF power is applied to, and creates heat in the workpiece.