4. HF WELDING TECHNIQUES

This section gives information on machine setting, weld area calculations and Appliqué welding.

4.1 MACHINE SETTING

4.1.1 Preparation

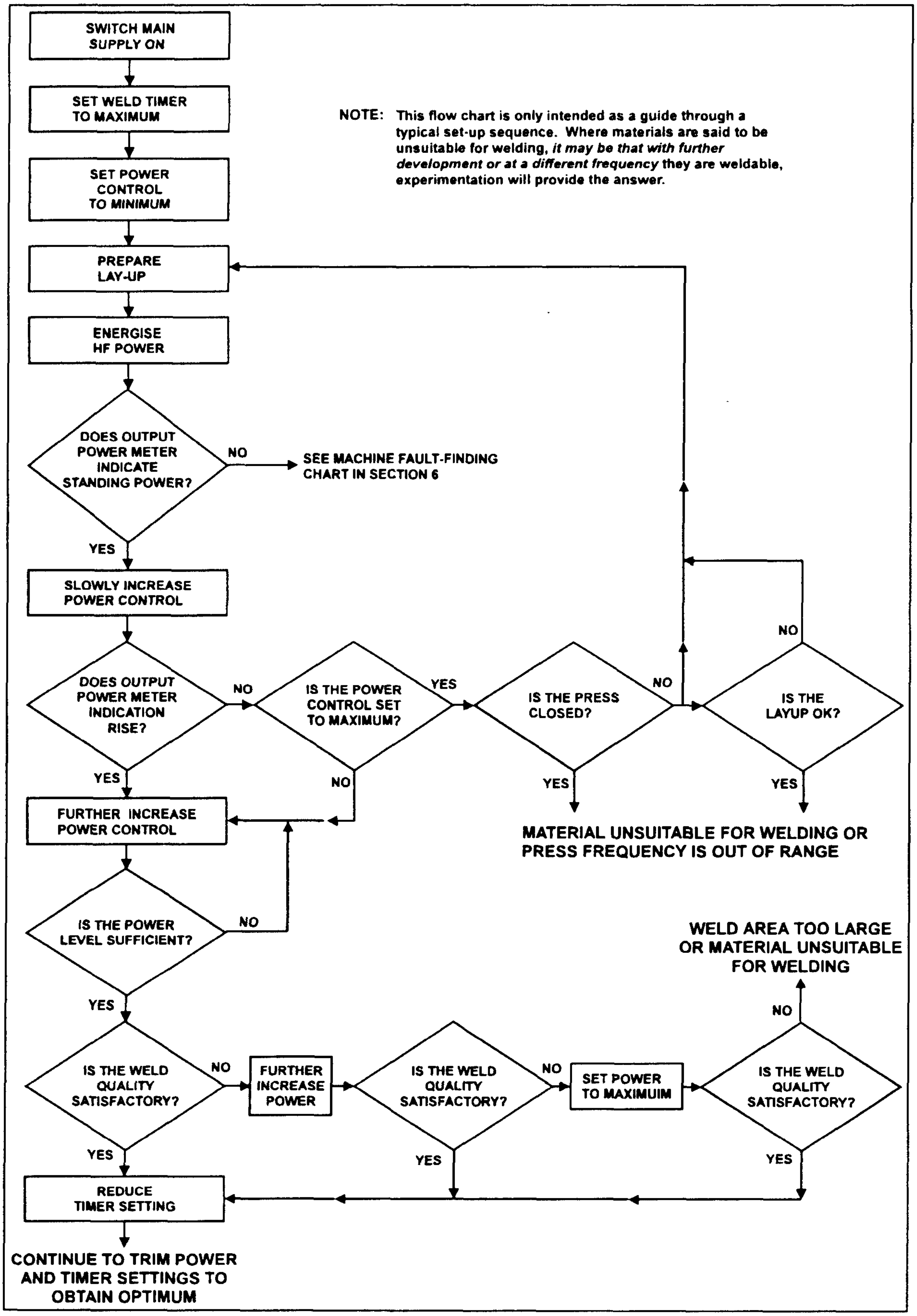
Setting a machine is first carried out when a new job is started and comprises the following main stages:

1. Selecting and fitting the tooling plate to the upper electrode.
2. Selecting and fitting the appropriate barrier material.
3. For linear indexing machines, feeding the workpiece webbs from the reels through the machine.
4. Ensuring that there is a sufficient supply of workpiece materials and other required components to hand.
5. Setting the machine controls to obtain the optimum weld.

Once the machine is in use, the settings are checked periodically, e.g. hourly or once a shift. During operation, if the quality of the welded products become unsatisfactory the cause should be investigated and the machine adjusted/repaired accordingly.

4.1.2 Setting the Controls

The Setting Adjustments required will vary from machine to machine and will also depend on the type of work to be carried out. The flow chart shown in Fig 4-1 gives a typical set up sequence.



NOTE: This flow chart is only intended as a guide through a typical set-up sequence. Where materials are said to be unsuitable for welding, *it may be that with further development or at a different frequency* they are weldable, experimentation will provide the answer.

Fig 4-1 - Typical Set-Up Flow Chart

4.2 WELD AREA CALCULATIONS

The HF power required to weld a given area depends upon a number of factors. In this sub-section, these factors will be described briefly and the relationship between HF power and weld area will be discussed. The formulae given should be regarded as a 'rule of thumb' from which to start setting the HF power level.

4.2.1 HF Generator Considerations

HF generators have a standing (quiescent) current, or base energy consumption which is required to supply the electrical circuits in readiness for welding. This base energy consumption is approximately 5% of the rated energy output and is taken from the incoming electrical supply during the whole period the welding machine circuits are energised.

The remaining available power (i.e. that above the base energy consumption) provides a weld area that is approximately proportional to the generator output. For example, a 6kW generator is capable of welding an area approximately twice that of a 3kW generator.

The efficiency of an HF generator is approximately 60%. This means that of the input power, 40% (including the base energy consumption) is dissipated as heat in the electrical circuits leaving 60% to be converted into HF power. Therefore a machine with a rated output of 6kW will require a supply of 10kW when operating at its maximum power output.

The maximum power output is only achieved when the electrode sinks into the workpiece materials. Thus during the period when the HF power is applied for the weld, the average power supplied to the electrode is considerably less than the maximum power output. Also, when taking the cooling time and time for unloading and loading components into account, the overall power consumption is a small fraction of that taken when the output power is at its maximum.

4.2.2 Basic Calculation of Required Power

The relationship between a given workpiece area and the HF power necessary to weld it has been established as typically 25 cm^2 per Kilowatt. This is an approximation based on welding two thicknesses of 0.010" (0.254 mm) PVC with a relatively wide plain electrode. In practice, depending on the factors discussed later, the welded area achieved per Kilowatt could be between 10 and 30 cm^2 or 2 to 5 $inches^2$.

To achieve a more realistic estimation of the weld area per Kilowatt, the following factors which affect the actual power requirement must be taken into consideration:

(a) Area of Weld	Approximately directly proportional to required power.
(b) Type of Material	The higher the loss factor of the material, the lower the power requirement.
(c) Thickness of Material	The thicker the PVC, the lower the power requirement due to reduced heat losses.

(d) Edge Factor	This is the total edge length of the welding electrode. long narrow electrode requires more power than a wid electrode of the same area.
(e) Length of Tear Seal Edge (if any)	Tear seal edges require more power than plain welds.
(f) Thickness and Type of Barrier Material	Less power is normally required when barrier material are used but increased electrode voltage will b necessary.
(g) Type and Design of Electrode	The heat conductivity of the electrode, whether it i temperature controlled and whether it incorporate components which absorb HF power.
(h) Required Welding Time	The shorter the required time, the larger the require power, but limiting factors also apply to avoid flashin at the electrode.

Consider the example quoted earlier of two thicknesses of 0.010" (0.254 mm) PVC with a relatively wide plain electrode requiring 1kW to weld 25 cm^2. For the same weld area using a tear seal weld on 0.005" (0.127 mm) PVC with a low vinyl content, only 0.5 kW would be required.

4.2.3 Realistic Calculation of Required HF Power

Based on some of the more important factors affecting the power requirement for a given weld configuration, a more realistic formula has been developed as follows:

$$\textbf{Power required (kW)} = \left(L \times \frac{1}{S} \times D\right) + \left(L \times \frac{2E}{1000}\right)$$

$$= L\left(\frac{D}{S} + 0.002E\right)$$

where

L = Length of weld in inches

D = Width of weld in inches plus 1/16" for tear seal electrodes

E = Watts loss per inch of electrode edge

S = Square inches of weld per kW

E and S variables

The value of the **E** and **S** variables depend on the thickness of the material being welded; for PVC, **E** and **S** are as follows:

PVC THICKNESS			
inches	mm	E	S
2 x 0.004	2 x 0.1016	3.0	2.0
2 x 0.005	2 x 0.1270	3.0	2.4
2 x 0.008	2 x 0.2032	3.5	3.4
2 x 0.012	2 x 0.254	4.0	4.2
2 x 0.20	2 x 0.508	5.0	5.0

HF Power / Weld Area Examples

The following table lists some examples calculated using the 'realistic' formula. Metric equivalents are shown in brackets.

SHEETING THICKNESS	WELD WIDTH	INCHES/kW	SQUARE INCHES/kW
2 x 0.005" (0.127 mm)	1" (25.4 mm)	2.36" (59.9 mm)	2.36 (15.27 cm^2)
2 x 0.01" (0.254 mm)		3.9" (99.1 mm)	3.9 (25.16 cm^2)
2 x 0.02" (0.508 mm)		4.75 (128.65 mm)	4.75 (30.65 cm^2)
2 x 0.005" (0.127 mm)	$^1/_4$" (6.35 mm)	9.1" (231 mm)	2.27 (14.66 cm^2)
2 x 0.012" (0.30 mm)		14.8" (376 mm)	3.7 (23.87 cm^2)
2 x 0.02" (0.508 mm)		17" (431 mm)	4.25 (27.4 cm^2)
2 x 0.005" (0.127 mm)	$^1/_8$" (3.175 mm)	17.1" (434 mm)	2.15 (13.87 cm^2)
2 x 0.012" (0.30 mm)		26.4" (670 mm)	3.3 (21.29 cm^2)
2 x 0.02" (0.508 mm)		30" (762 mm)	3.75 (24.19 cm^2)
2 x 0.0035" (0.089 mm)	$^1/_{16}$" (1.588 mm)	22" (559 mm)	1.37 (8.84 cm^2)
2 x 0.004" (0.1016 mm)		25.9" (658 mm)	1.62 (10.45 cm^2)
2 x 0.005" (0.127 mm)		30.4 (772 mm)	1.9 (12.26 cm^2)
2 x 0.008" (0.2032 mm)		39.2" (996 mm)	2.45 (15.8 cm^2)
2 x 0.012" (0.30 mm)		43.5" (1104 mm)	2.7 (17.4 cm^2)
2 x 0.02" (0.508 mm)		45" (1143 mm)	2.8 (18.1 cm^2)

Additional Factors to Consider

The 'realistic' formula is still very approximate and does not take into account many other factors such as:

(a) Generator Operating Frequency	Generators operating at, for example 50 MHz or 70 MHz will give better results on thin materials.
(b) Electrode Temperature	With electrodes at temperature appreciably above that of the PVC being welded, less power is required; the heat losses into the electrode during a weld are reduced, thus achieving more weld area.

(c) Barrier Material	Although the barrier presents a greater resistance to the flow of HF current, the power actually delivered can weld more square inches per kW, since the barrier material acts as a thermal insulator reducing the heat loss form the work into the electrode or workplate beneath. For thick materials, e.g. over 0.01" (0.254 mm) an extra 5% more square inches are possible, rising to over 10% for thin materials, e.g. under 0.005" (0.1270 mm). However, the nature and thickness of the barrier material will give different figures.
(d) Electrode Design	Complicated electrode designs and particularly those with spring inserts, bolster pads, locators etc., may require an extra 10% more power to balance the power losses in the electrode.
(e) Badly Tuned Load Circuit	With a generator badly matched to the electrode system, power is wasted in the system causing heating of generator components, feed strips etc. and reducing the effective weld area.

4.2.4 Practical Solution

From the information given so far, it is relatively simple to get an approximation of the required power by:

1. Calculating the weld area, allowing an extra $^1/_{16}$" (1.588 mm) for tear seal lengths.
2. Applying 2 inchs^2 to 5 inches^2 (12.9 cm^2 to 32.26 cm^2) per kW primarily according to material thickness and narrowness of weld.
3. Carrying out a sample test on the proposed welder for the job in question to get a more accurate answer.

The ultimate point show quickly can a good weld be achieved. All the preceding points are merely to establish that the generator has enough kW power to enable it to do the job in one operation.

Finally, remember that if the welder has insufficient power to do the weld in one operation, it may be possible to:

(a) Reduce the weld area (particularly the weld width).

(b) Heat the electrode or use a barrier material to meet marginal situations with thin materials.

(c) Use two or more operations to carry out the weld with separate, split, sprung or masked electrodes.

Calculation Examples

Example 1

To make tarpaulins using two overlapping pieces of 0.5 mm thick PVC with an electrode of 100 cm long x 2 cm wide, with a straight bar weld:

Area of weld: 100 cm x 2 cm = 200 cm^2

For 2 x 0.5 mm PVC use 25 cm^2/kW

Power required: (200 - 25) kW = 8kW

Example 2

Manufacturing an A4 book binder with two pieces of 0.25 mm thick PVC, with tear seal perimeter, on an automatic machine.

Area of perimeter: 160 cm x 2.5 mm = 40 cm^2

Extra 1.5 mm width for tear seal : 160 cm x 1.5 mm = 24 cm^2

Area of two spine bar weld: 60mm x 4 mm each 4 mm wide = 24 cm^2

Total area = 88 cm^2

For 2 x 0.25 mm PVC on an automatic machine allow 22 cm^2/kW

Power required: (88 - 22) kW = 4 kW

4.3 APPLIQUÉ WELDING

Appliqué decoration is an age-old method of ornamentation whereby one piece of material is cut out and attached to the surface of another. It might be found on a shield or a suit of armour, but more often as a decorative fabric stitched to another woven material.

Using PVC sheeting a decorative material permits HF bonding as a method of attachment to woven fabrics by mechanical bonding of melted PVC pushed between the threads or directly onto another PVC sheet. This attachment technique can be plain welding and it is easy to see the attraction of the next logical step, emulating tear-seal welding, which is to arrange for surplus PVC to be stripped away all around the tool impression.

A stripping tear may be found to be more easily started from a scissors cut into the surplus material toward the impressed profile, with the surplus PVC pulled horizontally over the impressed surface rather than directly away from the work piece.

4.3.1 Cost

Very impressive examples of appliqué welding have been produced, even including several colours of decorative PVC in the same impression, which show just what is possible with skilfully applied technique. Good results cannot be obtained with inappropriate technique anyway, but even when a tool and machine set-up is perfect the most important factor affecting the cost of processing is the time required for hand stripping and finishing when the work has left the welding machine.

4.3.2 Applications

The process can produce delicate and fancy decoration, most of its commercial appeal lies in reproducing striking simple artwork requiring little subsequent hand finishing.

4.3.3 Welding

Complications arising from fancy shapes and small size mean that most appliqué tools cannot be fabricated using bent brass rule bracketed to a baseplate. Where this construction is used the toolmaking must be meticulously accurate so far as the plane of the welding edges is concerned. For this reason they are best built directly on to thick baseplates rather than thin soleplates which may rely on welding pressure to flatten any residual curvature against their backing plates: this will not happen in appliqué welding where precise depth of sink control is essential.

We know that a pointed edge will cut through soft sheeting when sufficient force is applied to it, and in tear-seal welding this is undesirable until the temperature of the work material is raised by HF heating. However, in appliqué welding it seems there can be a distinct advantage when some mechanical cutting occurs before, or very early in the HF heating phase. To get this benefit we need to arrange that:

(a) the PVC is soft enough.

(b) tool pressure is appropriate.

(c) cutting penetrates no further than required.

Meeting this last condition requires a welding press in good condition, so that there is no sloppiness in the press head, which may be caused by press head keyways, with a downstroke limit stop adjustable with precision amounting to a small fraction of the thickness of the decorative sheeting. Tool pressures should also be adjustable and calibrated to enable effecting settings to be experimentally determined and noted. Experimentation can provided much useful information.

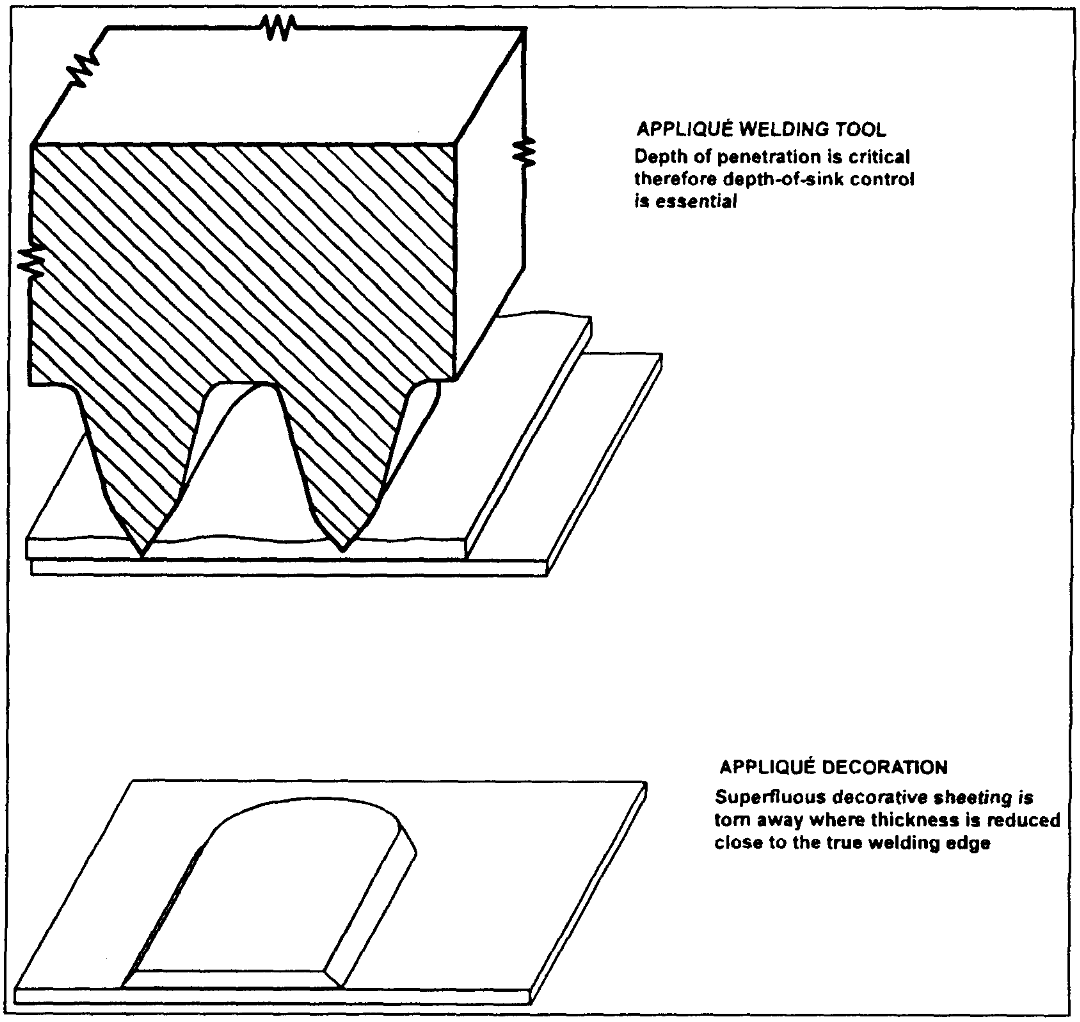
A barrier sheet to provide extra electrical insulation during bonding is virtually essential unless the base fabric is very thick.

Good appliqué welding results cannot be expected until the tool is heated. Operating temperature should always be less than the melting temperature of the PVC but the optimum temperature will vary with different sheeting, tools and technique. For example, pedal welding machines allow the tool to be brought into contact with the decorative sheeting to warm it up for a few moments before a follow through to full travel of the pedal switches on HF power for welding. This method may be advantageous or just the converse if the operator cannot reliably follow the required procedure to produce consistent results.

All other important variables are preset machine adjustments which provide repetitive accuracy, but some are interdependent. Tool pressure to produce an intended depth-of-sink need only be small if tool temperature is high, and HF heating time must be long enough for power output to stabilise at its intended level.

As this process is not viable unless clean stripping can be achieved, this is usually seen as the first objective in machine setting. A useful starting point is to set the depth stop so that the tool just touches the surface of the base sheeting when the decorative sheeting is absent to help accurate setting: it is dangerous to allow deeper penetration anyway.

Fig 4-2 shows a section through a tool edge and work material at the completion of a weld cycle in which penetration is prevented from reaching the level of the surface of the base material but has still reduced the thickness of the decorative sheeting close to the weld line so as to reduce its strength for a clean separating tear. Total thickness remains substantial so as to reduce spark hazard and to minimise the production of spew and degradation of the base sheeting. The intended appearance of the work after separation is also shown in the illustration but the actual width of the weld produced (the area fused together at the interface) will depend on the power input.



APPLIQUÉ WELDING TOOL
Depth of penetration is critical therefore depth-of-sink control is essential

APPLIQUÉ DECORATION
Superfluous decorative sheeting is torn away where thickness is reduced close to the true welding edge

Fig 4-2 - Appliqué Welding

5. MAINTENANCE

The maintenance of HF welding machines falls into two categories, preventive maintenance and faultfinding/repair.

Preventive maintenance is the regular cleaning, lubrication, inspection and testing of a machine to keep it in good working order and to prevent breakdowns.

Faultfinding and repair are carried out after a machine has broken down or is not operating correctly, to restore the machine to good working order.

Preventive maintenance is discussed in this section and fault finding on machines and welds is discussed in Section 6.

5.1 PREVENTIVE MAINTENANCE

One aspect of HF welding which is often overlooked, is the regular maintenance of the welding machinery. Regular checks on the machinery can often reveal potential problems well before any damage is caused. This will minimise any downtime caused by damage to the machines, and expensive component renewal. The important rule is "prevention is better than cure!"

To ensure that maintenance is not overlooked, it is suggested that a maintenance schedule is drawn up for each machine. This simply lists the maintenance tasks and how often they need to be carried out. For maintenance details of specific machines, read the manufacturer's manuals supplied with the machine.

WARNINGS

1. **MAINTENANCE MUST ONLY BE CARRIED OUT BY PERSONNEL QUALIFIED TO DO SO AND WHO ARE AWARE OF THE RISKS INVOLVED.**

2. **WELDING MACHINES ARE SUPPLIED WITH ELECTRICAL SUPPLIES WHICH CAN BE LETHAL. THEREFORE ANY MAINTENANCE ON ELECTRICAL CIRCUITS MUST ONLY BE CARRIED OUT BY QUALIFIED ELECTRICIANS.**

3. **DO NOT REMOVE ANY COVERS OR PANELS FROM ELECTRICAL CIRCUITS UNLESS:**

   (A) THE RELEVANT ELECTRICAL ISOLATOR(S) HAVE BEEN LOCKED OFF AS REQUIRED BY SECTION 12 OF THE ELECTRICITY AT WORK REGULATIONS.

   (B) ANY STORED ENERGY HAS BEEN DISSIPATED OR DISCHARGED TO EARTH.

5.1.1 Cleaning

To ensure that a machine continues to operate efficiently and safely it must be kept clean and free from debris. Moving parts can become obstructed, preventing smooth operation of the machine and changing setting adjustments. Electric motors and air intakes to HF generators can become clogged with debris, causing overheating and a potential fire hazard.

The work area around machines should also be kept clean and tidy to minimise the risk of personnel slipping, tripping etc.

5.1.2 Lubrication

To ensure the smooth running, and long life, of any mechanical system, including welding machines, lubrication is essential. All lubrication should be carried out in accordance with the manufacturers instructions at the specified intervals and with the specified lubricants. Generally, lubrication should cover the following items:

a) Oil levels in gearboxes, dashpots etc. should be checked weekly. Follow the manufacturer's instructions regarding oil and filter changes, ensuring that the specified lubricants and components are used.

b) Drive chains and shafts should be lubricated sparingly as recommended by the manufacturer.

c) Grease nipples and lubrication points should be lubricated as recommended by the manufacturer.

5.1.3 Inspection

For the safe running of any welding machine, there should be regular inspections to check the following:

a) All safety guards are functional and fitted correctly.

b) All drive chains and drive belts are undamaged, fitted correctly and tensioned correctly.

c) All wiring is routed safely and is undamaged.

d) All electrical connections are secure.

e) All air intakes are free from obstruction.

5.1.4 Testing

The welding machines should be regularly tested. These tests should check all aspects of the machine's operation. For example, they should be checked to ensure that they operate correctly and safely, and at all times conform to any local safety standards including levels of RF emissions.

6. FAULT FINDING

This section gives help for faultfinding on HF welding machines and welds.

The faultfinding on machines is limited to general problems which should be easily solved by trained personnel. For detailed faultfinding refer to the machine manufacturer's maintenance manuals.

6.1 HF WELDING MACHINES

WARNINGS

1. **FAULT FINDING MUST ONLY BE CARRIED OUT BY PERSONNEL QUALIFIED TO DO SO AND WHO ARE AWARE OF THE RISKS INVOLVED.**

2. **WELDING MACHINES ARE SUPPLIED WITH ELECTRICAL SUPPLIES WHICH CAN BE LETHAL. THEREFORE ANY MAINTENANCE ON ELECTRICAL CIRCUITS MUST ONLY BE CARRIED OUT BY QUALIFIED ELECTRICIANS.**

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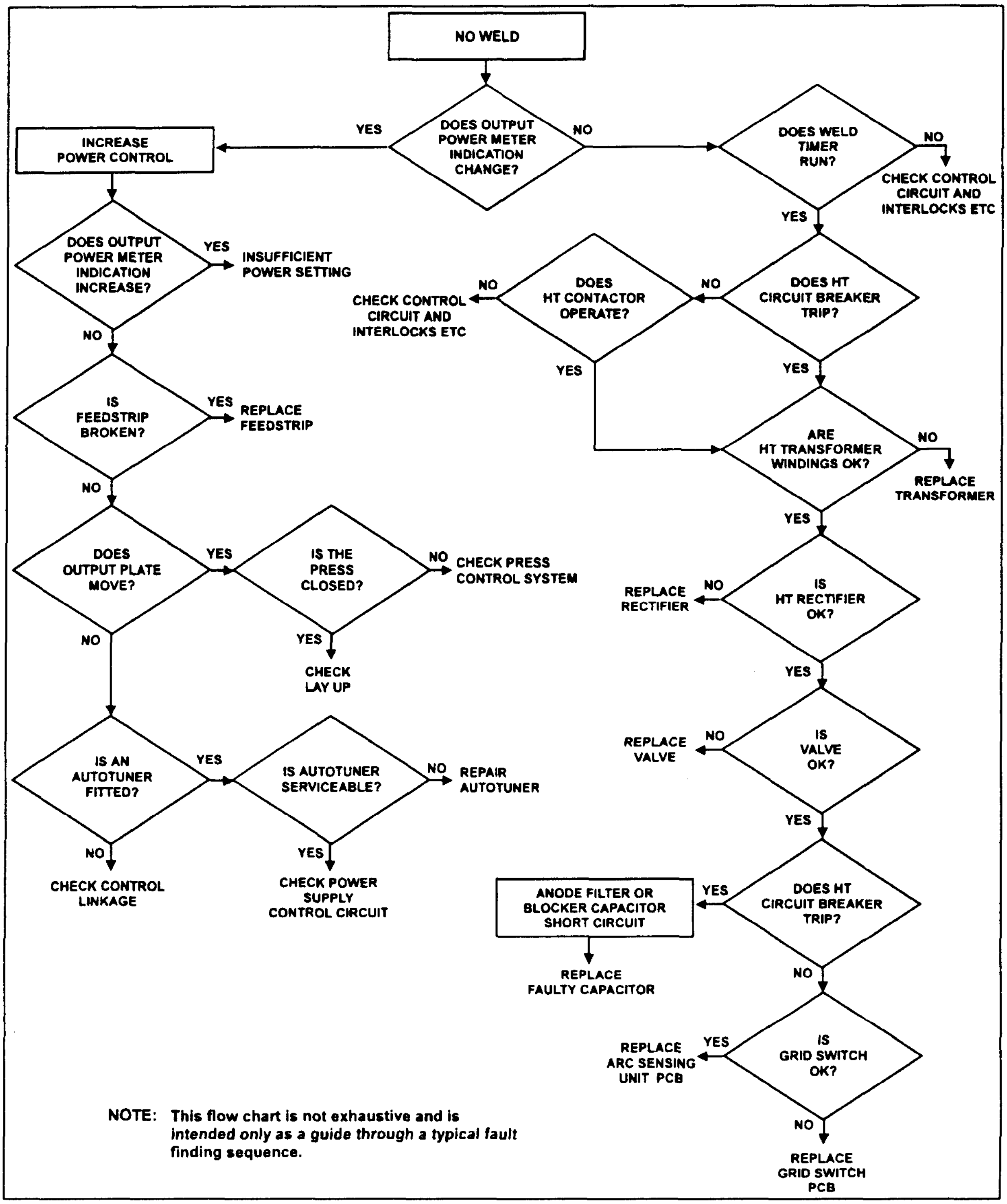
The following fault finding charts are for general guidance only, they are not exhaustive and are only intended as a guide through typical fault finding sequences.

SYMPTOM	POSSIBLE CAUSE	ACTIONS
Power On indicator unlit	1. Electrical supply to machine not switched on.	Check the main incoming circuit breaker and Power On switch.
	2. Fuse blown or circuit breaker tripped.	Check fuses and circuit breakers. If blown or tripped, investigate the cause and repair any fault before replacing fuse or remaking a circuit breaker.
	3. Wiring open circuit or loose/broken electrical connections.	Check wiring, terminals and switches.
	4. Power On indicator unserviceable.	Renew indicator.
Power available but machine does not run.	1. Safety interlock open circuit.	Check that all guards are correctly fitted and that any interlocked panels are in place.
	2. Emergency Off pushbutton pressed in.	Check that all Emergency Off pushbuttons are released. To release twist the pushbutton and pull outwards.
	3. Process interlock open circuit.	Check the function of all mechanical, thermal and flow interlocks.
	4. Mechanical 'jam'	Check that all mechanical moving parts are free to move and are unobstructed. Especially check for jammed workpieces or other product components.



NOTE: **This flow chart is not exhaustive and is *intended only as a guide through a typical fault* finding sequence.**

Fig 6-1 - Typical Welding Machine Fault Finding Sequence Flow Chart

6.2 WELDS

The weld fault finding chart shown in Fig 6-2 lists weld faults and their possible causes.

FAULTS	CAUSES																																																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Weld opens up	●		●		X	●		●	X							●				●		●		●		●					●	●	●	●													X	●			●	●
Film breaks on edge of weld				●			●						●	●			●				●	●		●			●	●		●	●							●		●												
Film breaks within weld							●				●	●		●	●		●							●				●		●																						
Poor resistance to tear propagation				●							●	●	●	●	●											●	●																									
Bursting of tear seal on inflation							●					●		●					●				●																●													
Tear seal not properly welded (ragged tear line)	●	●				●									●			●		●		●	●	●	●															●								●			●	
Deformed welds					●	●		●																																●												
Formation of bulges and blisters on reverse side of weld		●		●						●																●																										
Poor weld impression and variation within weld					●	●		●								●	●				●			●																												
Gloss variation next to weld				●																	●																				●											
Air inclusion in welded articles with card inserts																																										●	●									
Formation of folds (corrugation)																													●															●	●	●	●					
Tendency to arcing (especially with thin or rigid films)		●		●		●						●				●				●		●	●		●										●	●	●												●	●	●	
Surface scorching						●		●															●											●	●																	
Large surface welding : (Differential energy distribution)	●					●																●		●																												●

X = Refers only to the bonding of film to coated boards

CAUSES KEY

1 HF output insufficient
2 HF output too high
3 Welding time too short
4 Welding time too long
5 Cooling time too short
6 Pressure too low
7 Pressure too high
8 Depth stop incorrectly set
9 Electrode too narrow
10 Electrode too wide
11 Book cover spine weld too narrow
12 Faulty weld design
14 Electrode penetrates too deeply (especially on folding welds)
15 Difference in height of weld to tear seal too small
16 Difference in height of weld to tear seal too high
17 Height of electrodes does not match differential thickness of layer
18 Tear seal too blunt
19 Tear seal too sharp
20 Temperature of electrode too low (where heater box is used)
21 Temperature of electrode too high (where heater box is used)
23 Damaged or dirty tools
24 Insufficient rigidity in electode mountings
25 Unsuitable barrier material
26 Thermal barrier material too thick
27 Film too brittle
28 Card inserts too tight-fitting
29 Tension due to shrinkage of film
30 Excessive stress
31 Wear on electrode
32 Delamination of surface coatings
33 Plasticiser exudation
34 Dirty surface
35 Conductive printing inks
37 Packaged material electrically conductive
38 Layers of different hardness
39 Material layers too thick in contour (tear-seal) welding
40 Torn when too warm
41 Film tendency to gloss
42 Missing or insufficient packing
43 Card insert too thin
44 Film not destrained
45 Disregarding orientation of film
46 Film used have greatly different thickness
47 If adhesive coated, type of adhesive unsuitable
48 Excessive weld area/generator output ratio
49 Too small weld area/generator output ratio
50 Unfavourable generator characteristics
51 Material unsuitable for welding
52 Maladjusted standing wave correctors

Fig 6-2 - Weld Fault Finding Chart