8.

Resistance Spot Welding, Resistance Projection Welding and Resistance Seam Welding

Figure 8.1 shows an extract from the classification of the welding methods according to DIN 1910 with a detailed account of the conductive resistance pressure welding.

In the case of resistance pressure welding, the heating occurs at the welding point as a consequence of Joule resistance heating caused by current flow through an electrical conductor, Figure 8.2. In spot and projection welding, the plates to be welded in overlap. Current supply is carried out through spherical or flat electrodes, respectively. In roller seam welding, two driven roller electrodes are applied. The plates to be welded are mainly overlapped. The heat input rate Q_{input} is generated by resistance heating in a current-carrying conductor, Figure 8.3. However, only the effective heat quantity Q_{eff} is instrumental in the formation of the weld nugget. Q_{eff} is composed of the input heat minus the dissipation heat. The heat loss arises from the heat dissipation into the electrodes and the plates and also from thermal radiation.

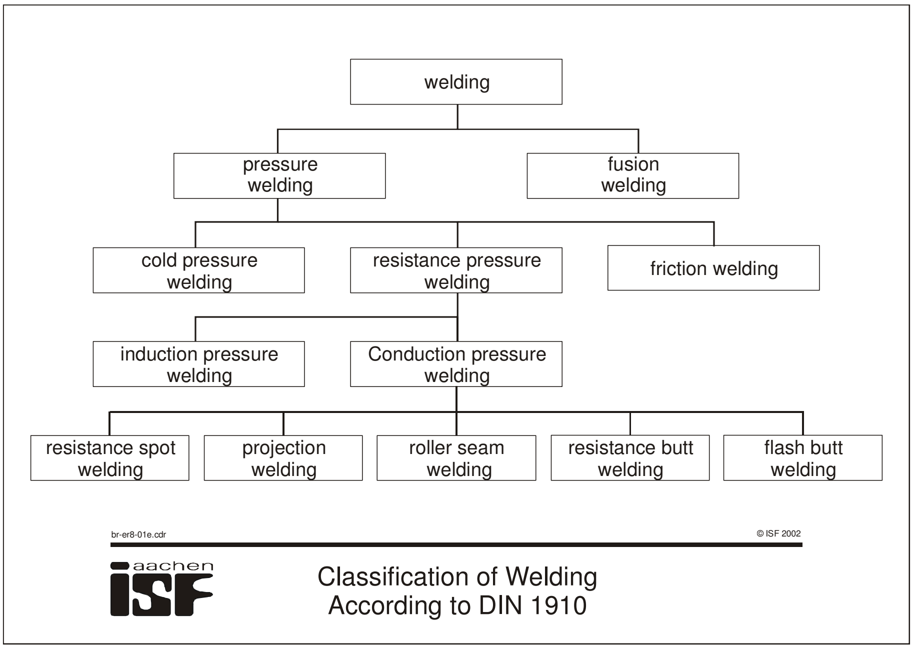


Figure 8.1

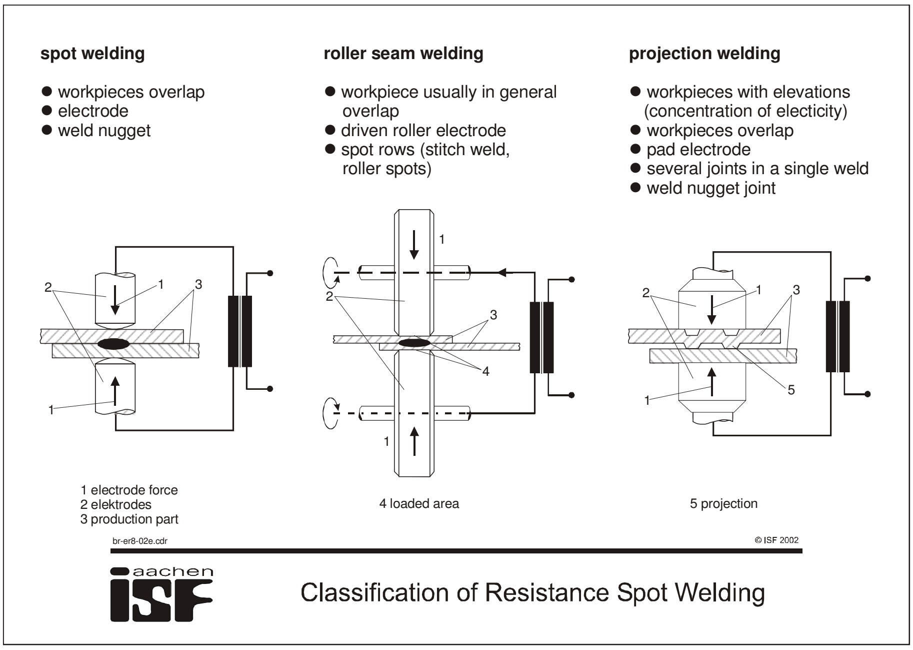


Figure 8.2

The resistance during resistance heating is composed of the contact resistances on the two plates and of their material resistance. The reduction of the electrode force down to 90% increases the heat input rate by 105%, the reduction of the welding current down to 90% decreases the heat rate to 80% and a welding time reduction to 90% decreases the heat rate to 92%.

The time progression of the resistance is shown in Figure 8.4. The contact resistance is composed of the interface resistances between the electrode and the plate (electrode/plate) and between the plates (plate/plate). The resistance height is greatly dependent on the applied electrode force. The higher this force is set, the larger are the conductive cross-sections at the contact points and smaller the resistances. The contact surfaces, which are rapidly increasing at the start of welding, effect a rapid reduction of interface resistances.

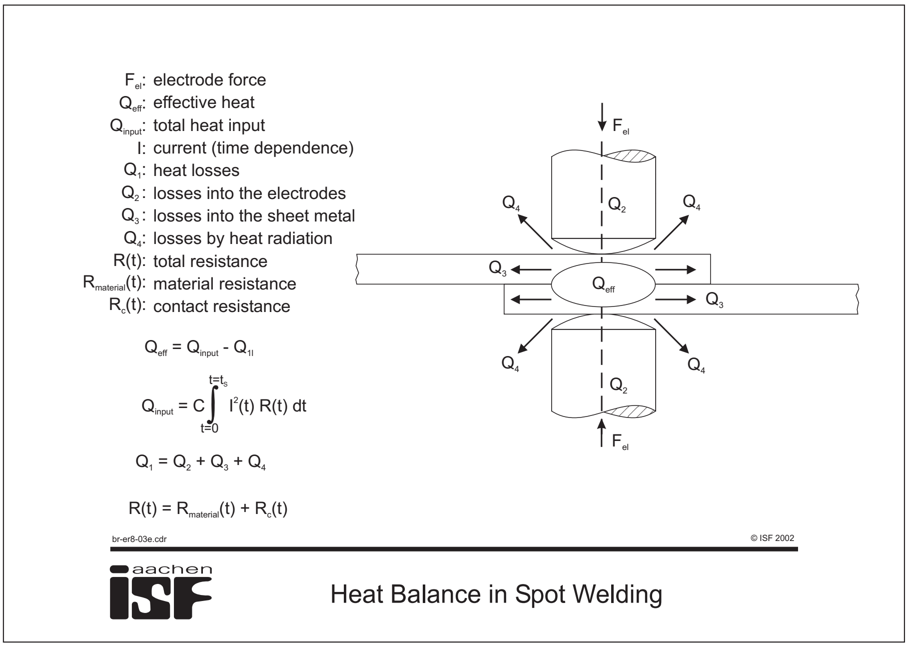


Figure 8.3

With the formation of the weld nugget the interface resistances between the plates disappear. During the progress of the weld the material resistance increases from a low value (surrounding temperatures) to a maximum value above the melting temperature.

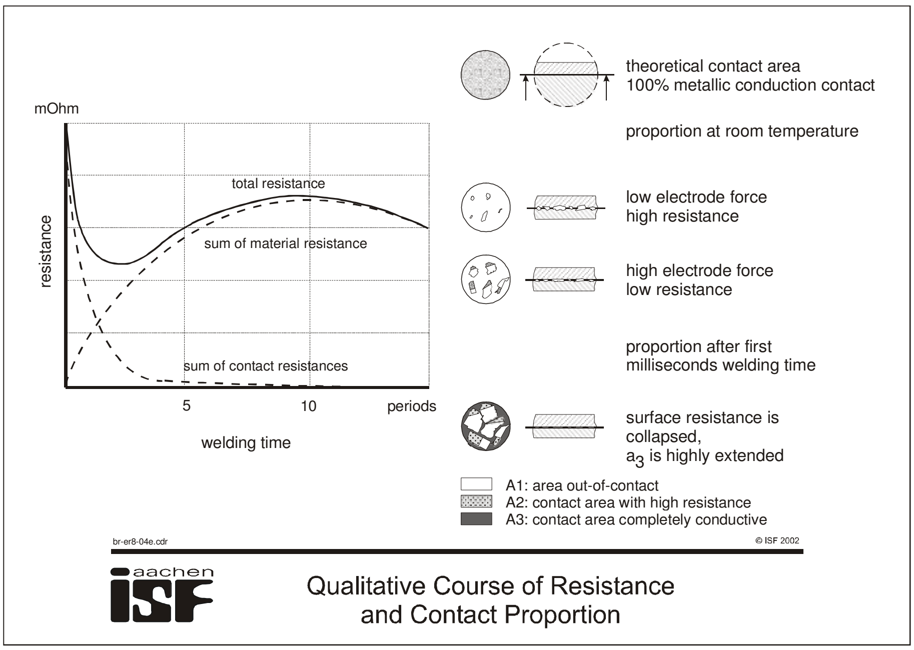


Figure 8.4

Figure 8.5 shows diagrammatically the different resistances during the spot welding process with acting electrode force, but without welding current. Weld nugget formation must therefore start in the joining zone because of the existing high contact resistance there.

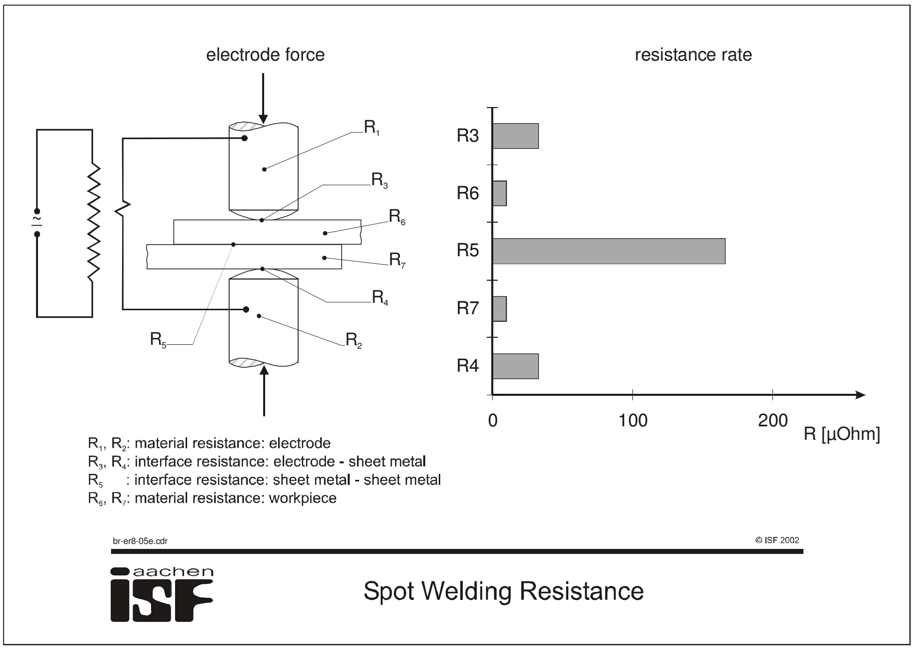


Figure 8.5

Figure 8.6 shows directly cooled electrodes for resistance welding. The coolant is normally water. In the cooling tube, the cooling water is transported to the electrode base. The diagram shows the temperature distribution in the electrodes and in the plates. The maximum temperature is reached in the centre of the weld nugget and decreases strongly in the electrode direction.

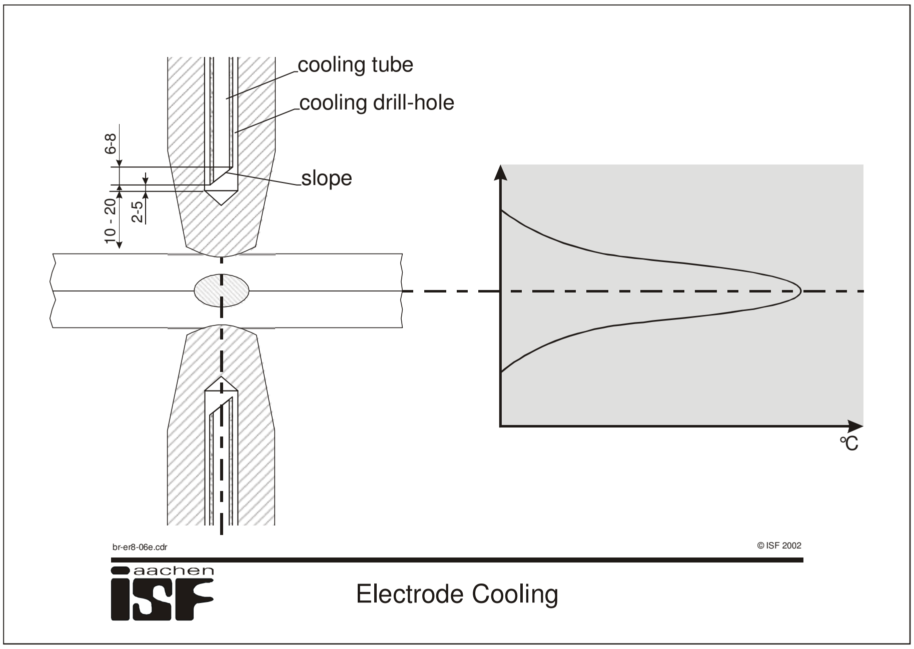


Figure 8.6

Sequence of a resistance spot welding process, Figure 8.7:

1->2 Lowering of the top electrode

2->3 Application of the adjusted electrode force Set-up time t_{pre}, sequence

3->4 Switching-on of the adjusted welding current for the period of the welding time t_w. Formation of the weld nugget in the joining zone of both workpieces.

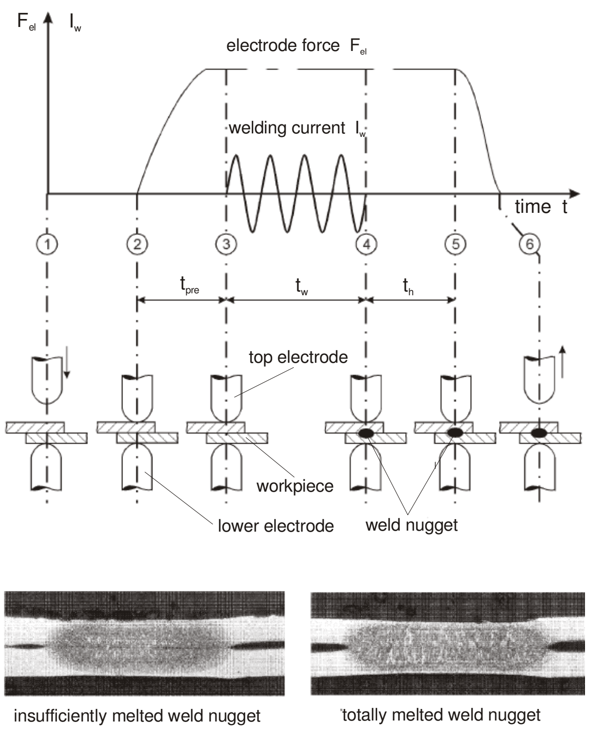
An example shows the macrosection of a weld nugget after the welding time has ended.

4->5 Maintaining the electrode force for the period of the set post-weld holding time t_h.

5->6 Switching-off the force generating system and lifting the electrodes off the workpiece.

The functions of the set-up time and the post-weld holding time are listed in Figure 8.8. Dependent on the welding task **different force and current programs can be set in the welding machines**, Figure 8.9. In the top the simplest possible welding program sequence is shown: The application of the electrode force, the set-up time sequence t_{pre}, the switching-on of the welding current and the sequence of the welding time t_w, the sequence of the post-weld holding time t_h and the switching-off of the force generating system. The diagram in the centre is almost identical to the one just described.

Merely in the welding current range, welding is carried out using an adjustable current rise (7) and current decay (8). The diagram below depicts a more sophisticated current program. In addition, welding is carried out with a variable electrode force (2) and with preheating (4) and post-heating current (6). Dependent on the control system, the process can be influenced by adjustment.



br-er8-07e.cdr © ISF 2002

aachen ISF

Time Sequence of Resistance Spot Welding

Figure 8.7

set-up time

- compressing the workpiece
- build-up of electrode force to preset value
- setting-up of reproducible resistance before welding
- electrode resting after bounce
- preventing resting of electrode on workpiece under electricle voltage

postweld-holding time

- holding time of workpiece during cooling of molten metal
- prevention of pore formation in the welding nugget
- prevention of lifting the electrode under voltage

The postweld-holding time has influence on the weld point hardening within certain limits.

br-er8-08e.cdr © ISF 2002

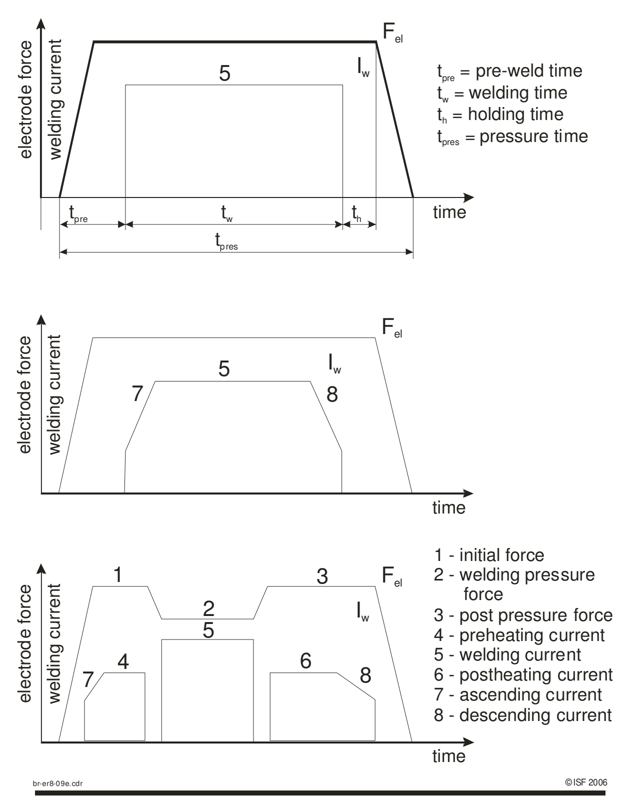
aachen ISF

Functions of Pre- and Postwelding

Figure 8.8

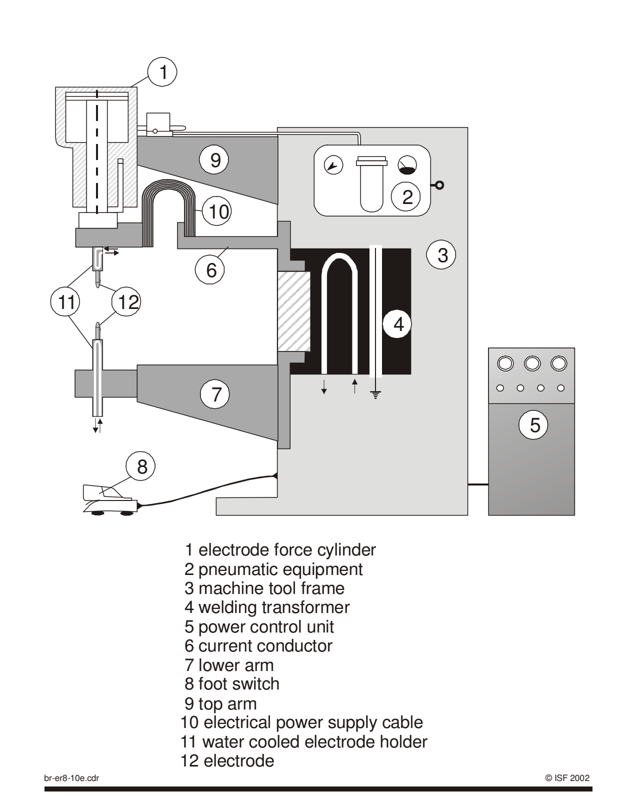
A controlled variable may be, for instance, the electrode path, the resistance progress, the welding current or the welding voltage.

Figure 8.10 shows the **principle structure of a resistance spot welding machine**. The main components are: the machine frame, the welding transformer with secondary lines, the electrode pressure system and the control system. This principle design applies to spot, projection and roller seam welding machines. Differences are to be found merely in the type of electrode fittings and in the electrode shapes.



Course of Force and Current

Figure 8.9

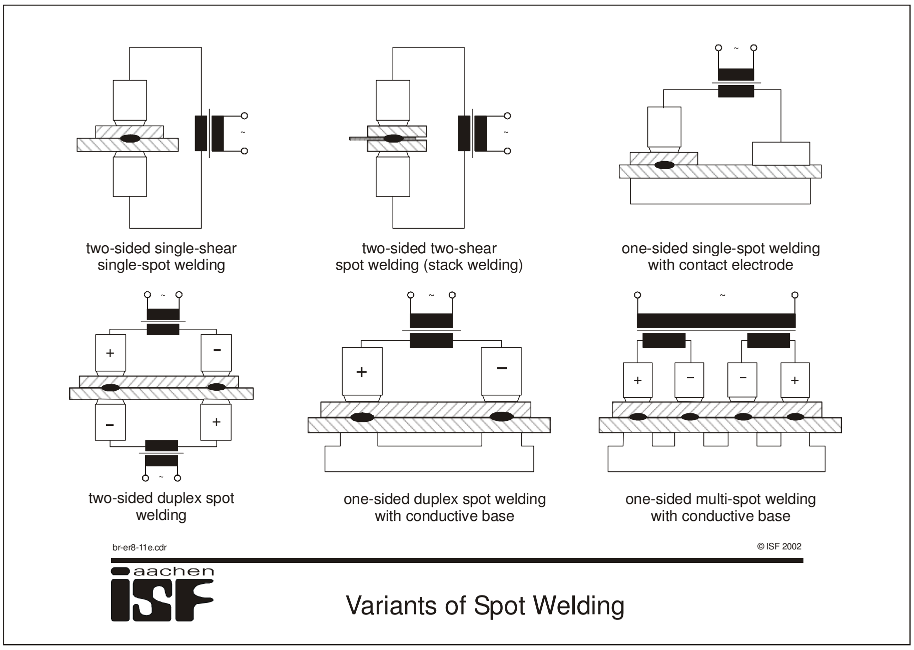


Schematic Assembly of Spot Welding Machine

Figure 8.10

Figure 8.11 depicts the possible **process variations** of resistance spot welding. These are distinguished by the number of plates to be welded and by the arrangement of the electrodes or, respectively, of the transformers. It has to be noted that with a corresponding arrangement also plates can be welded where one of the two plates has a non-conductive surface (as, for example, plastics).

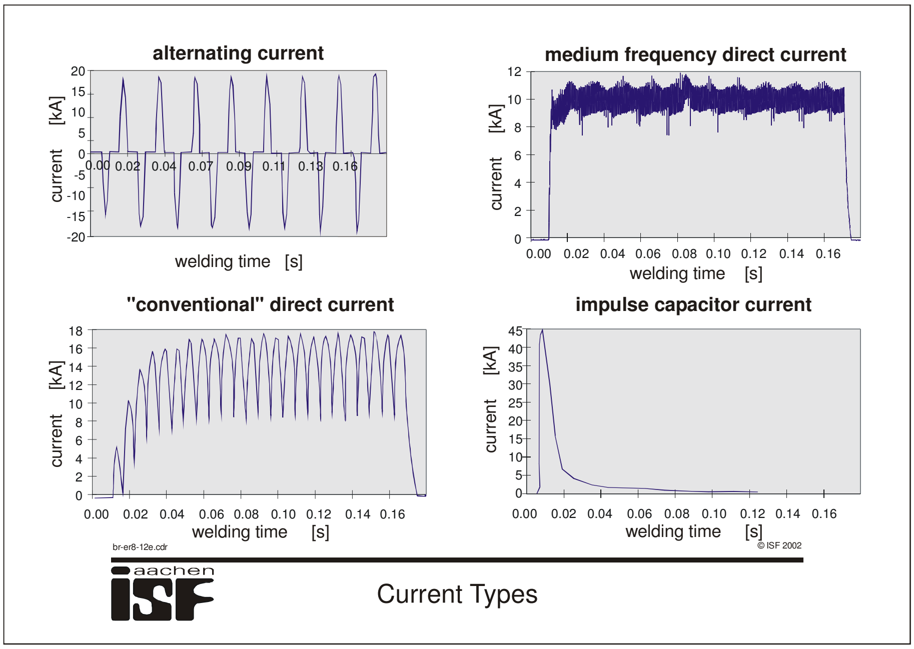
Figure 8.12 shows the current types which are normally used for resistance welding. Alternating current has the simplest structure (Figure 8.13) and is most price effective, unavoidable are, however, the disadvantages of current zeros and weld nugget cooling. In relation to the average current values, peak loads occur and, with that, increased electrode wear. These extreme peak loads do not occur with direct current.



Figur 8.11

The structural design of a d.c. supply unit is, however, more complicated and, therefore, more expensive than an a.c. supply unit.

As conventional welding machines operate with a 50 Hz primary current supply, the welding current can be controlled only in 20 ms units (1 period). When the inverter-direct current technique or, respectively, the medium-frequency technique is used, a finer setting of the current-on period and a more precise control of the welding current is possible.



Figur 8.12

In order to realise higher currents and shorter welding times, the impulse capacitor resistance welding technique is applied. The rectified primary current is stored in capacitors and, through a high-voltage transformer, converted to

high welding currents. The advantages of this technique are low heat input and high reproducibility. Because of the high energy density, materials with good conductivity can be welded and also multiple-projection welds can be carried out. A disadvantage of this method is, apart from the high equipment costs, the difficult regulation of the welding current.

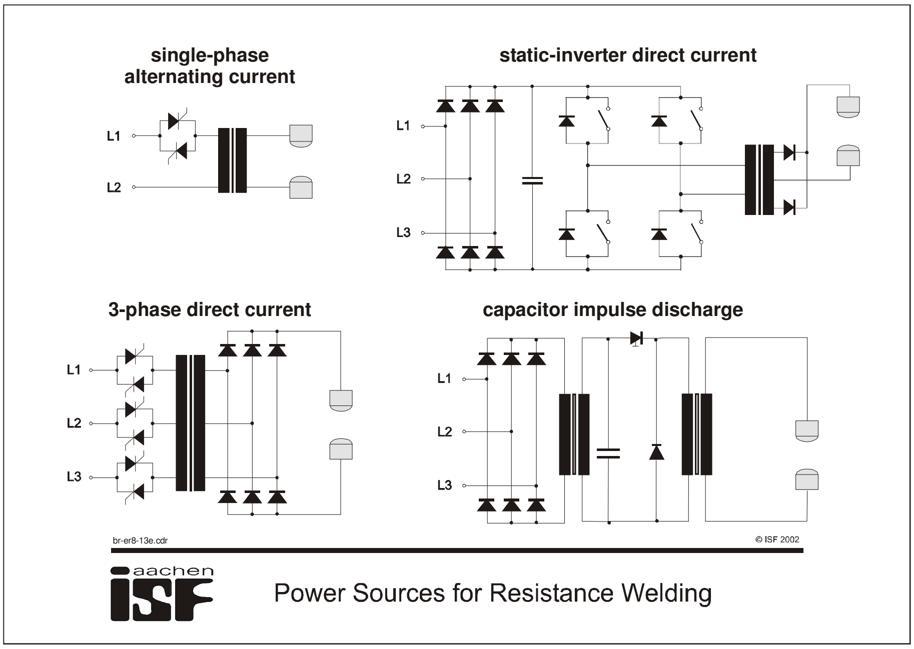


Figure 8.13

Electrodes for spot resistance welding have the property of transferring the electrode force and the welding current. They are **wearing parts** and, therefore, easily replaceable.

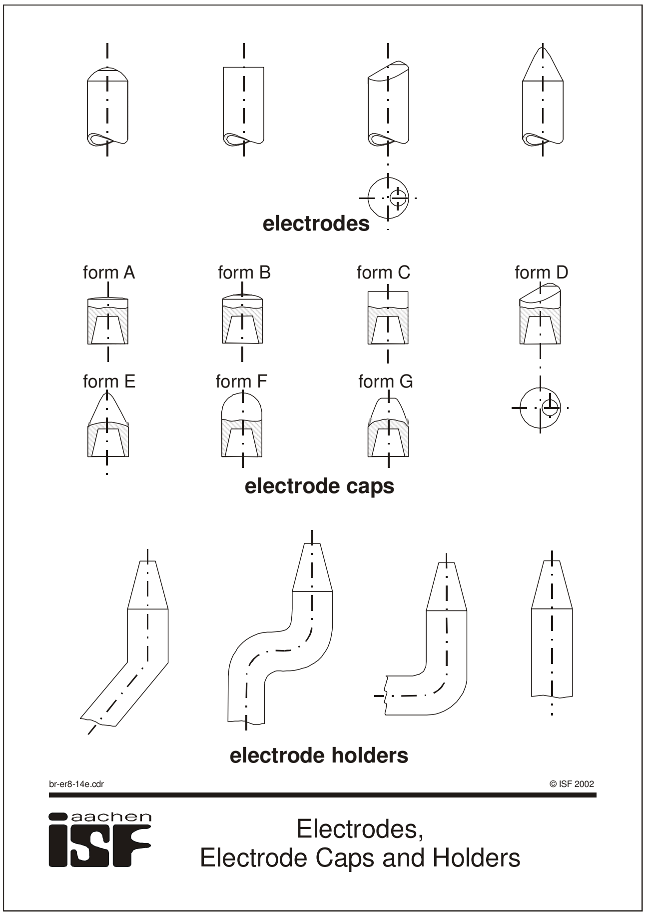


Figure 8.14

requirements

- good electrical conductivity
- good thermal conductivity
- high high-temperature strength
- high temperature stability
- high softening temperature
- little tendency to alloying with workpiece material
- easy options in machining

ISO 5182			Key
Group	Type	No.	
A	1	1	Cu - ETP
		2	Cu Cdl
	2	1	Cu Crl
		2	Cu Crl Zr
	3	1	Cu CO2 Be
		2	Cu Ni2 Si
	4	1	Cu Ni1 P
		2	Cu Be2 Co Ni
		3	Cu Ag6
		4	CuAl10NiFe5Ni5

ISO 5182			Key
Group	Type	No.	
B	10		W75 Cu
	11		W78 Cu
	12		WC70 Cu
	13		Mo
	14		W
	15		W65 Ag

br-er8-15e.cdr © ISF 2002

aachen ISF

Electrode Materials

Figure 8.15

Depending on the shape and type of electrode, **solid electrodes or electrode caps**, must be either remachined or recycled. Figure 8.14 depicts various types of electrodes, electrode caps and holders.

Dependent upon the electrode application, different alloyed electrode materials are used, Figure 8.15. The added alloying elements influence the red hardness, the tempering resistance, the conductivity, the fusion temperature, the electrode alloying tendency, and, finally, the machinability of the electrode material. When beryllium is used as an alloying element, the admissible MAC values must be strictly adhered to during remachining or dressing of the electrodes.

Already during the **design phase** of the components to be welded, importance must be attached to a good accessibility of the welding point. Moreover, the **electrode force** which is imperative to the process must be applied in a way that no damage is done to the workpiece. In the ideal case, the welding point is accessible from the top and from below, Figure 8.16.

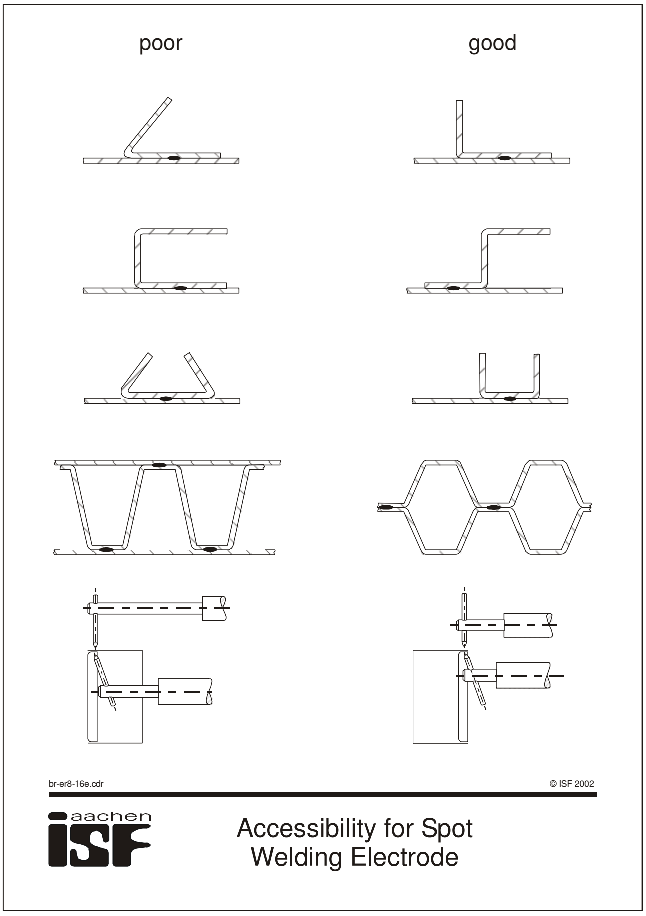


Figure 8.16

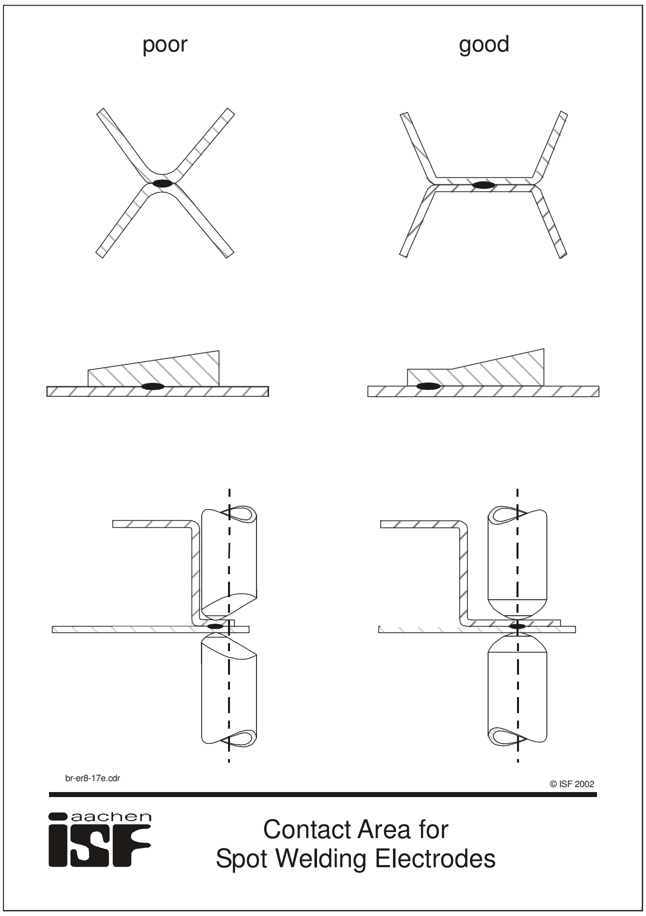


Figure 8.17

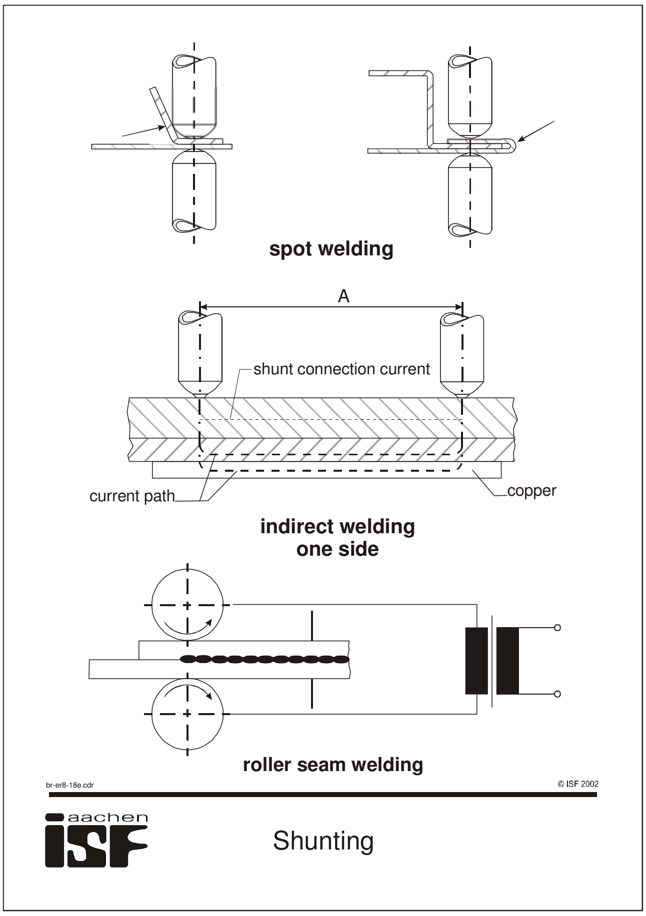


Figure 8.18

In order to avoid the displacement of the electrodes, the **electrode working surface** must be **flat**. Also during the design phase space must be provided for an adequately large clearing zone around the working point, in order to guarantee the unimpeded electrode approach to the working point, Figure 8.17.

Dependent on the joining job, the process variation, or the resistance welding method, a so-called **"shunt current/effect"** may be noticed. This current component, as a rule, does not contribute to the formation of the weld nugget; under certain circumstances it might even prevent a reliable welding process. In the example, shown in Figure 8.18, the shunt current leads to undesired fusing contacts and, because of the lacking electrode force at this point, also to damages to the plate surface.

If unsuitable welding parameters have been set, **weld spatter** formation may occur, Figure 8.19. Liquid molten metal forms on the plate surface or in the joining zone. The reasons for this kind of process disturbance are, for example, too low an electrode force with regard to the set welding current or welding time, too high an energy input with regard to the plate thickness or too small an edge distance of the welding point.

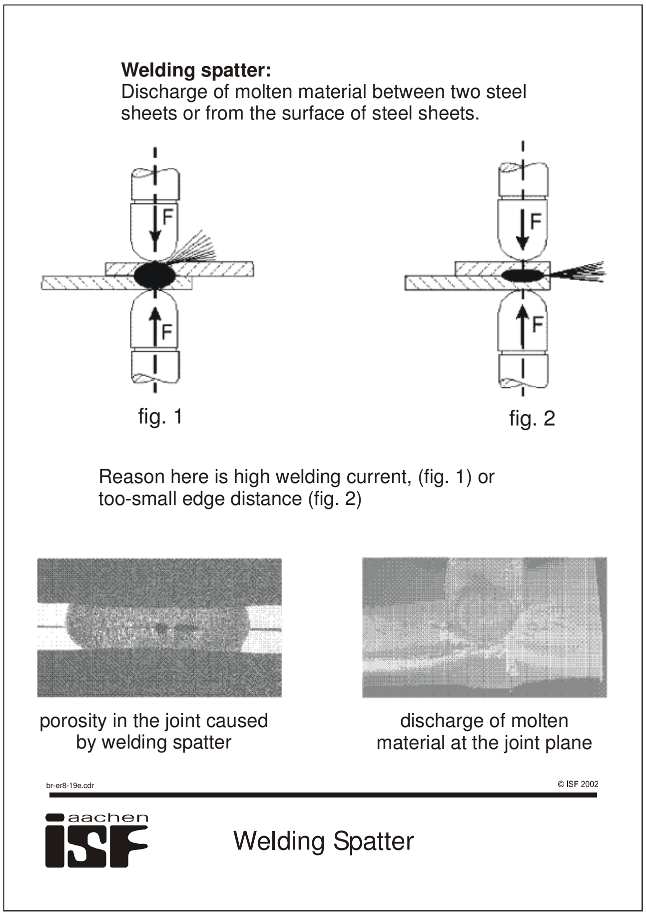


Figure 8.19

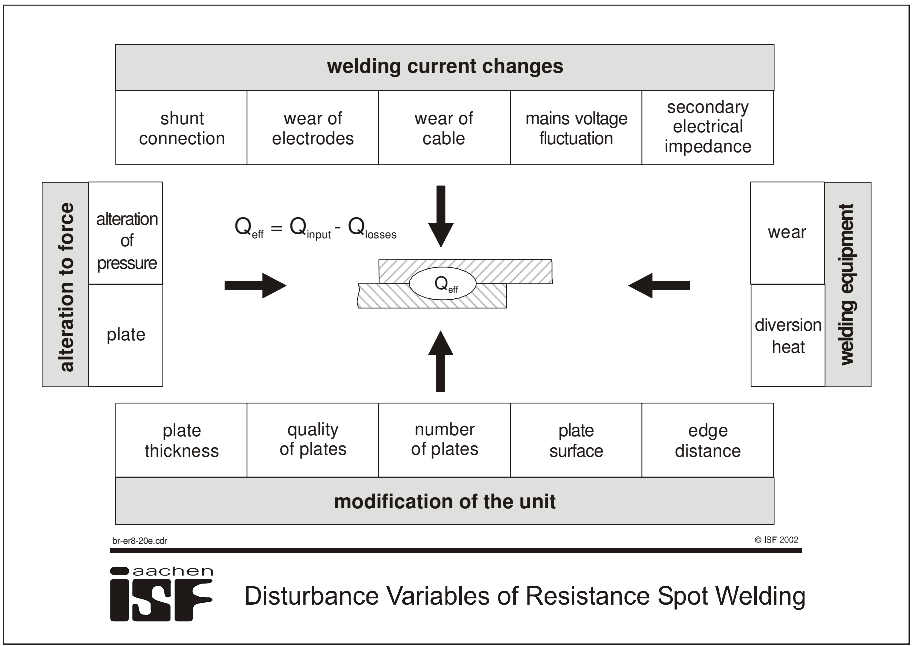


Figure 8.20

Figure 8.20 shows a list of a large number of possible disturbances in resistance spot welding. **Welding current changes** are caused by: shunt, electrode wear, cable wear, mains voltage variations, secondary impedance.

Different welding conditions are caused by welding machine wear, different heat dissipation. Non-uniform conditions by alterations to components are: different plate thicknesses, plate quality, number of plates, plate surfaces, edge distances. **Electrode force changes** are caused by: pressure fluctuations and -changes, plate bouncing.

The resistance spot welding method allows welding of a large number of materials. A list of the various **materials** is shown in Figure 8.21. The alloying elements which are used for steels have a varying influence on the suitability for resistance spot welding. The values which are indicated in the table are valid only when the stated element is the sole alloying constituent of the steel material.

Figure 8.22 shows a **comparison between resistance spot and resistance projection welding**. The fundamental difference between the two methods lies in the definition of the current transition point.

materials	weld-ability
aluminium	satisfactory
iron	very good
gold	satisfactory
cobalt	very good
copper	poor
magnesium	good
molybdenum	satisfactory
nickel	very good
platinum	very good
silver	very good
tantalum	very good
titanium	very good
tungsten	satisfactory

weldable materials

alloying elements	good weldability	sufficient weldability
	maximum content [%]	
C	0,25	0,40
C + Cr	0,35	1,60
C + Mo	0,50	0,70
C + V	0,40	0,60
C + Mn	1,40	1,60
C + Ni	3,00	4,00
Si	0,40	1,00
Cu	0,60	0,60
P + S	0,10	0,10
C+Cr+Mo+V	0,60	1,60

influence of alloying elements (steel materials)

br-er8-21e.cdr © ISF 2002

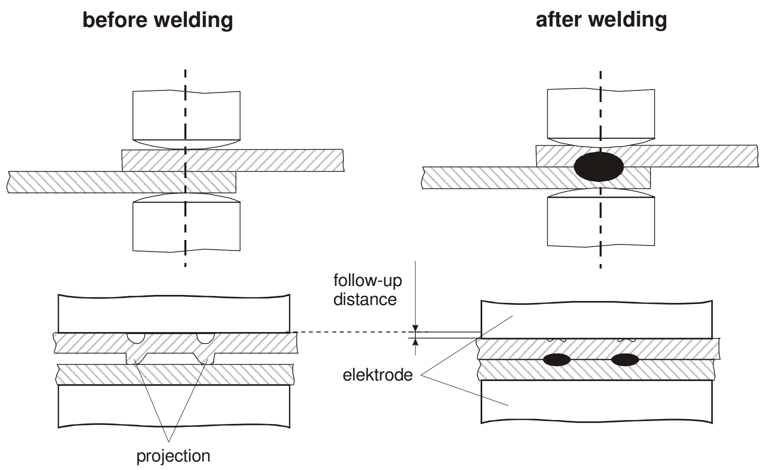
aachen ISF

Weldable Materials

Figure 8.21

The differences between both methods are illustrated in Figure 8.23. The short life of the electrodes used for resistance spot welding is explained by the higher thermal load and the larger pressing area caused by the smaller electrode contact areas. The term “electrode life” stands for the number of welds that can be carried out with one pair of electrodes without further rework and without exceeding the tolerances for quality criteria of the weld.

Depending on the demands on the joint strength or on the projection rigidity, different projection shapes are applied. These are annular, circular or longitudinal projections. The welding projections are, accord-



br-er8-22e.cdr © ISF 2002

aachen ISF

Comparison of Resistance Spot and Projection Welding

Figure 8.22

	spot welding	projection welding
elektrodes:		
diameter	up to 20 mm	> 20 mm
tip face	convex	flat
electrode life	less	longer
place where the nugget originates	elektrodes	projections
number of welding nuggets	one	several
follow-up distance	small	big
problems:		
current distribution	no	yes
force distribution	no	yes

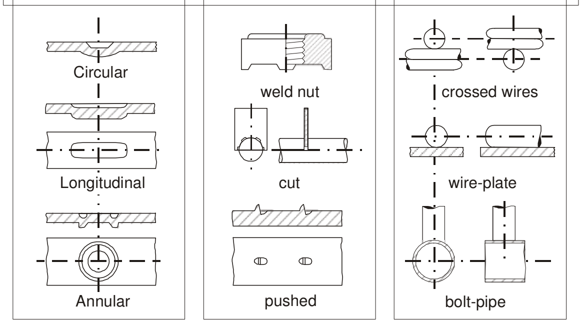
br-er8-23e.cdr © ISF 2002

aachen ISF

Differences Between Resistance Spot and Projection Welding

Figure 8.23

embossed projection shape	solid projection shape	natural projection shape
pressed mould pressed	struck machined cut pushed	
circular longitudinal annular	circular longitudinal annular interrupted annular	spot contact line contact



br-er8-24e.cdr © ISF 2002

aachen ISF

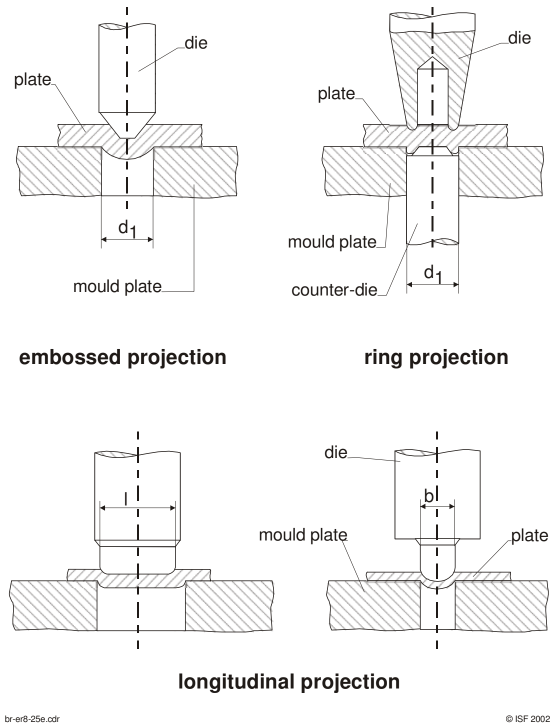
Customary Projection Shapes

Figure 8.24

ing to their size, adapted to the used plate thickness and may, therefore, appear as different types in the workpiece: embossed projections, solid projections and natural projections. The survey is shown in Figure 8.24.

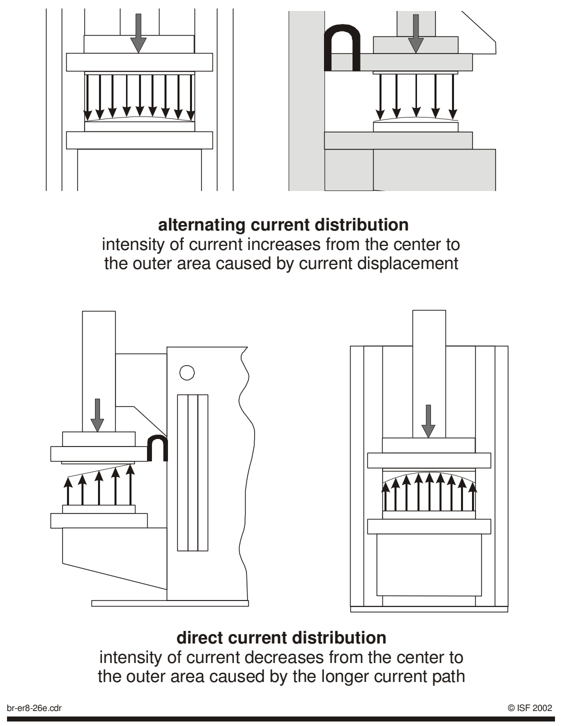
In Figure 8.25 the production of embossed projections in different shapes is shown. The shape is embossed onto the plate surface by appropriate die plates, dies and, if necessary, counter dies.

Various **problems** occur in **projection welding** caused by the welding of several joints in a single working cycle. Due to different current paths - when using direct current - and a current displacement - when using alternating current -, welding nuggets with differing quali-



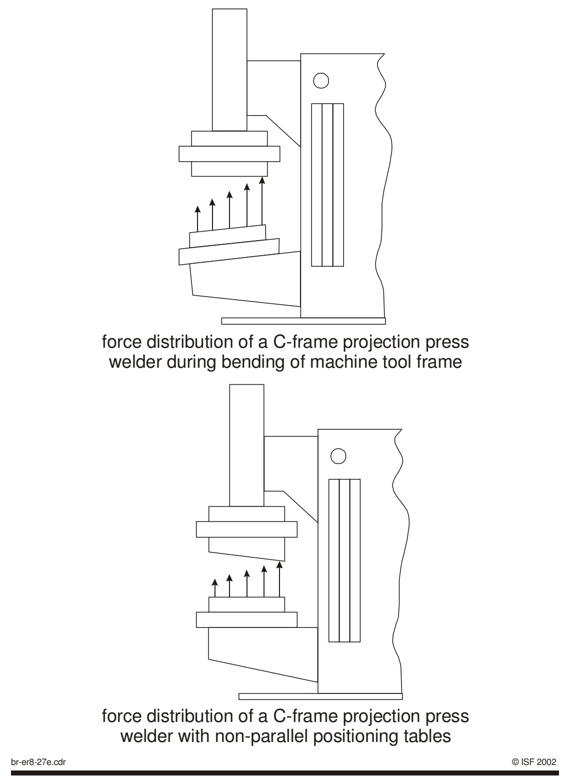
Production of
Embossed Projection Shapes

Figure 8.25



Problem of Current Distribution
During Projection Welding

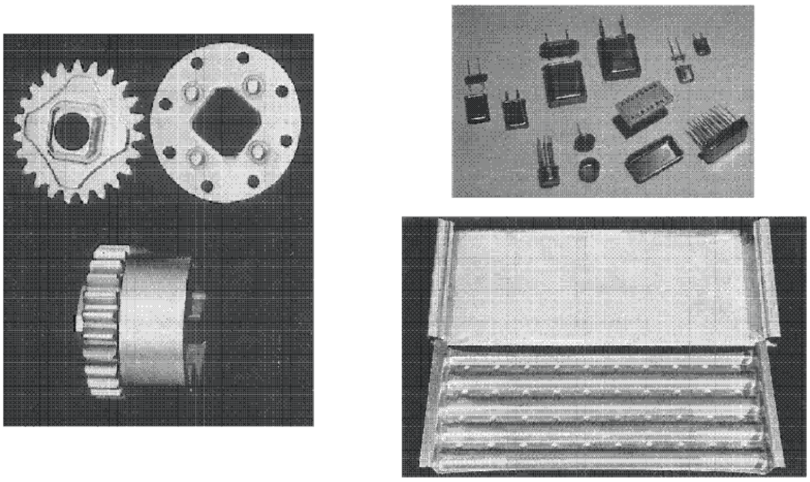
Figure 8.26



Problems of Force Distribution
During Projection Welding

Figure 8.27

ties are produced when no preventive remedies are taken, Figure 8.26.



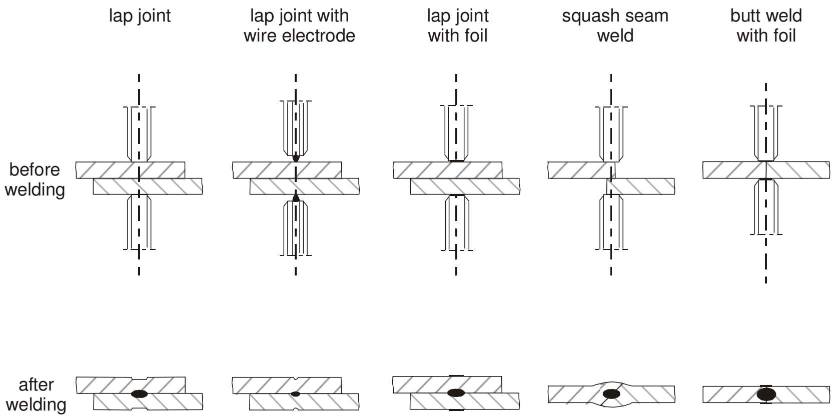
Application Examples of Projection Welding

Figure 8.28

A varying force distribution, as shown by the example in Figure 8.27, also leads to differing qualities of the produced weld nuggets.

In Figure 8.28 several examples of application using projection welding are depicted. In this example, the shapes are of the embossed type.

Figures 8.29 and 8.30 show several process variations of roller seam welding. Seam welding is actually a continuous spot welding process, but with the application of roller electrodes. In contrast to resistance spot welding the electrodes remain in contact and turn continuously after the first weld spot has been produced. At the points where a welding spot is to be produced again current flow is initiated. Dependent on the electrode feed rate and on the welding current frequency, spot welds or seal welds with overlapping weld nuggets are produced. The application of d.c. current also produces seal welds.



Roller Seam Welding

Figure 8.29

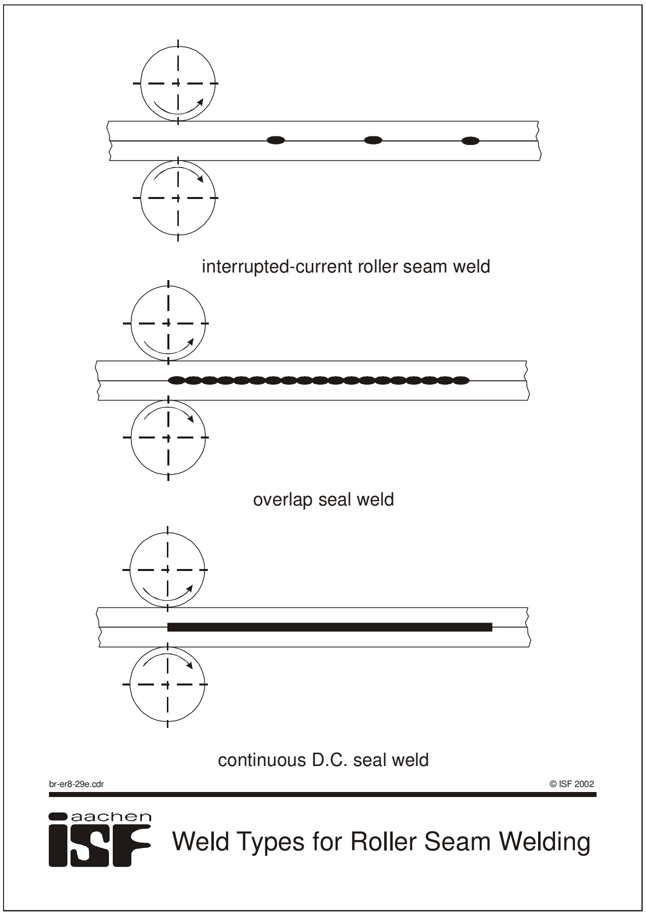

interrupted-current roller seam weld
overlap seal weld
continuous D.C. seal weld
br-er8-29e.cdr
© ISF 2002
aachen ISF
Weld Types for Roller Seam Welding

Figure 8.30