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(54) Welding apparatus

(57) A method of pulse welding wherein information characteristic of a weld pulse is collected by a probe (21), is amplified (25), passed to an A/D converter (27) and passed to a central processing unit (29) which compares that information with standard information from a store (30) and produces information descriptive of the nature of the weld pulse comparable to a desired weld pulse.

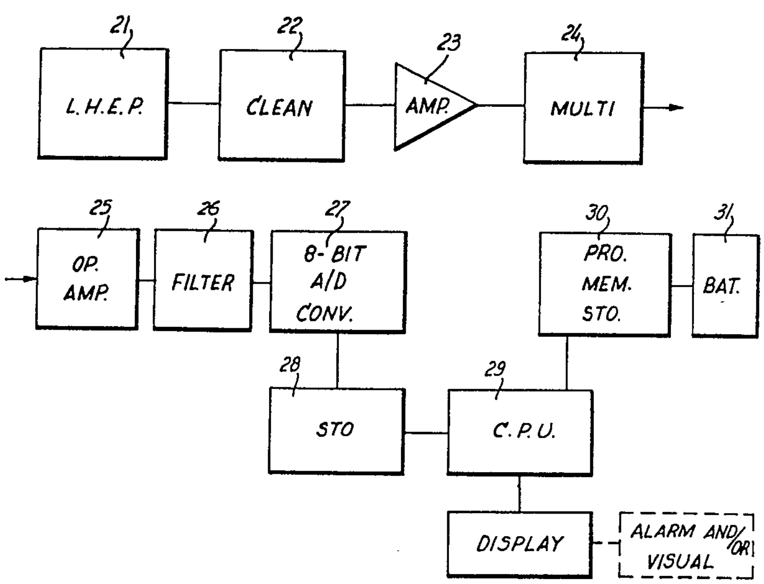

FIG. 6

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

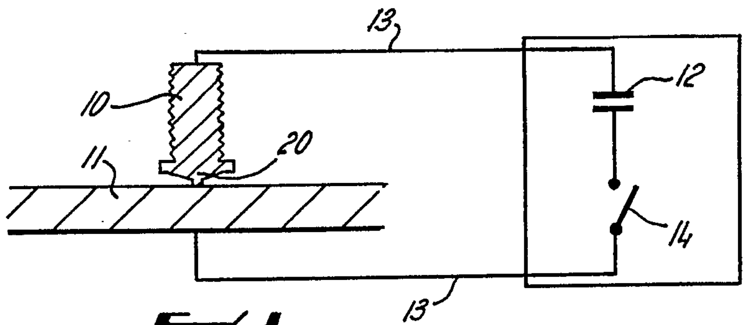

FIG.1

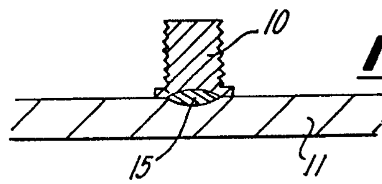

FIG.2

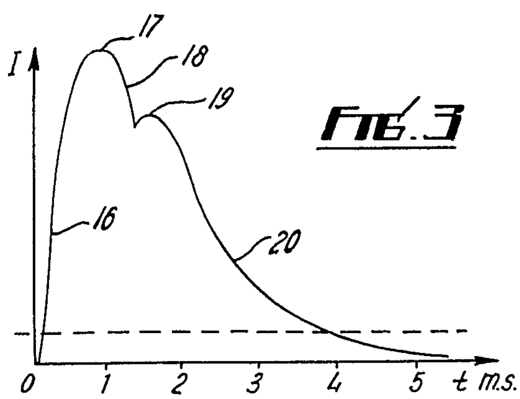

FIG.3

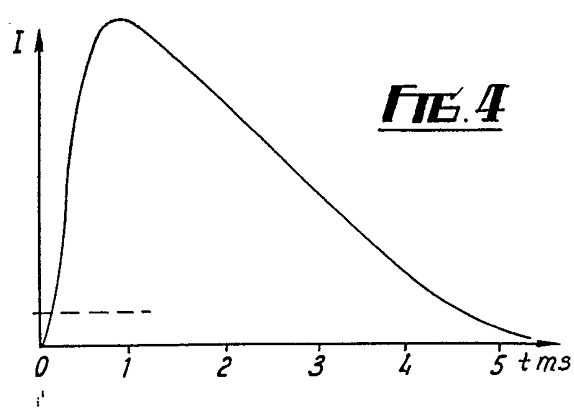

FIG.4

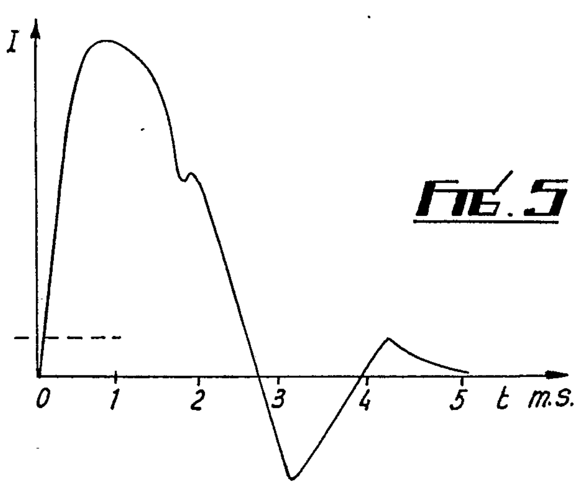

FIG.5

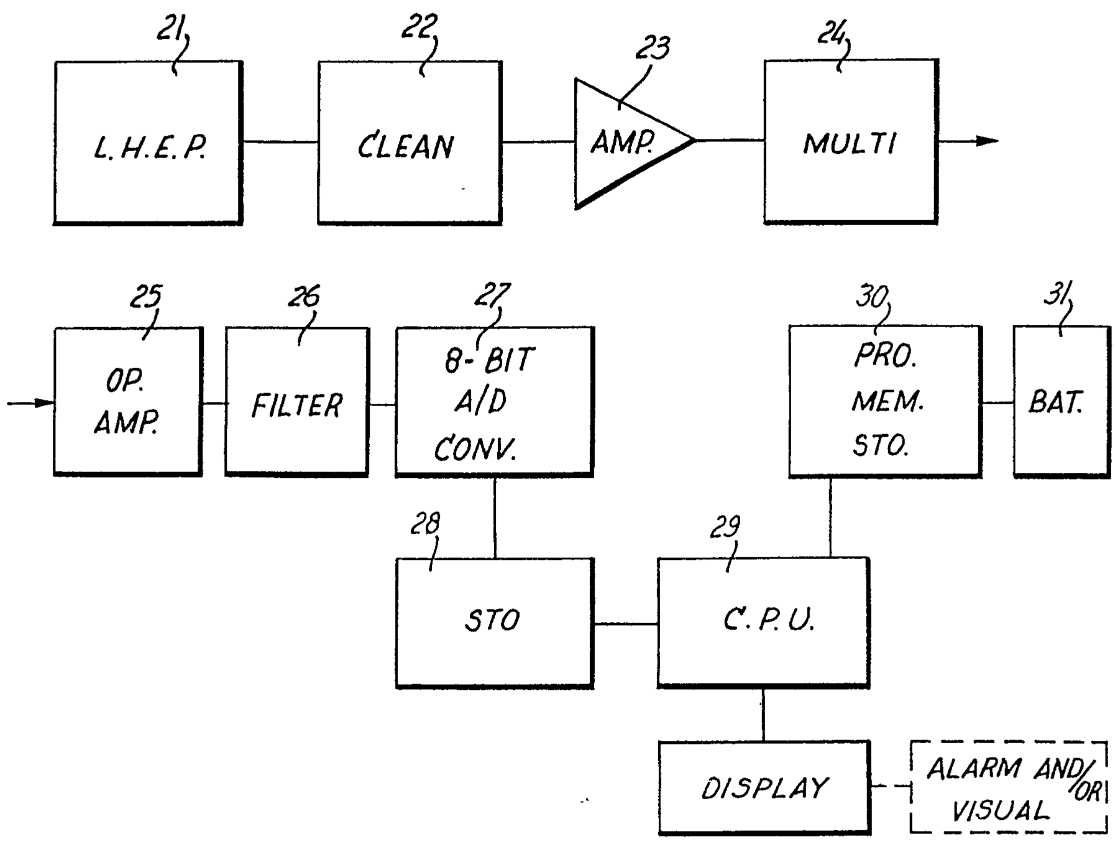
21
L.H.E.P.
22
CLEAN
23
AMP.
24
MULTI
25
OP. AMP.
26
FILTER
27
8-BIT A/D CONV.
30
PRO. MEM. STO.
31
BAT.
28
STO
29
C.P.U.
DISPLAY
ALARM AND/OR VISUAL

FIG. 6

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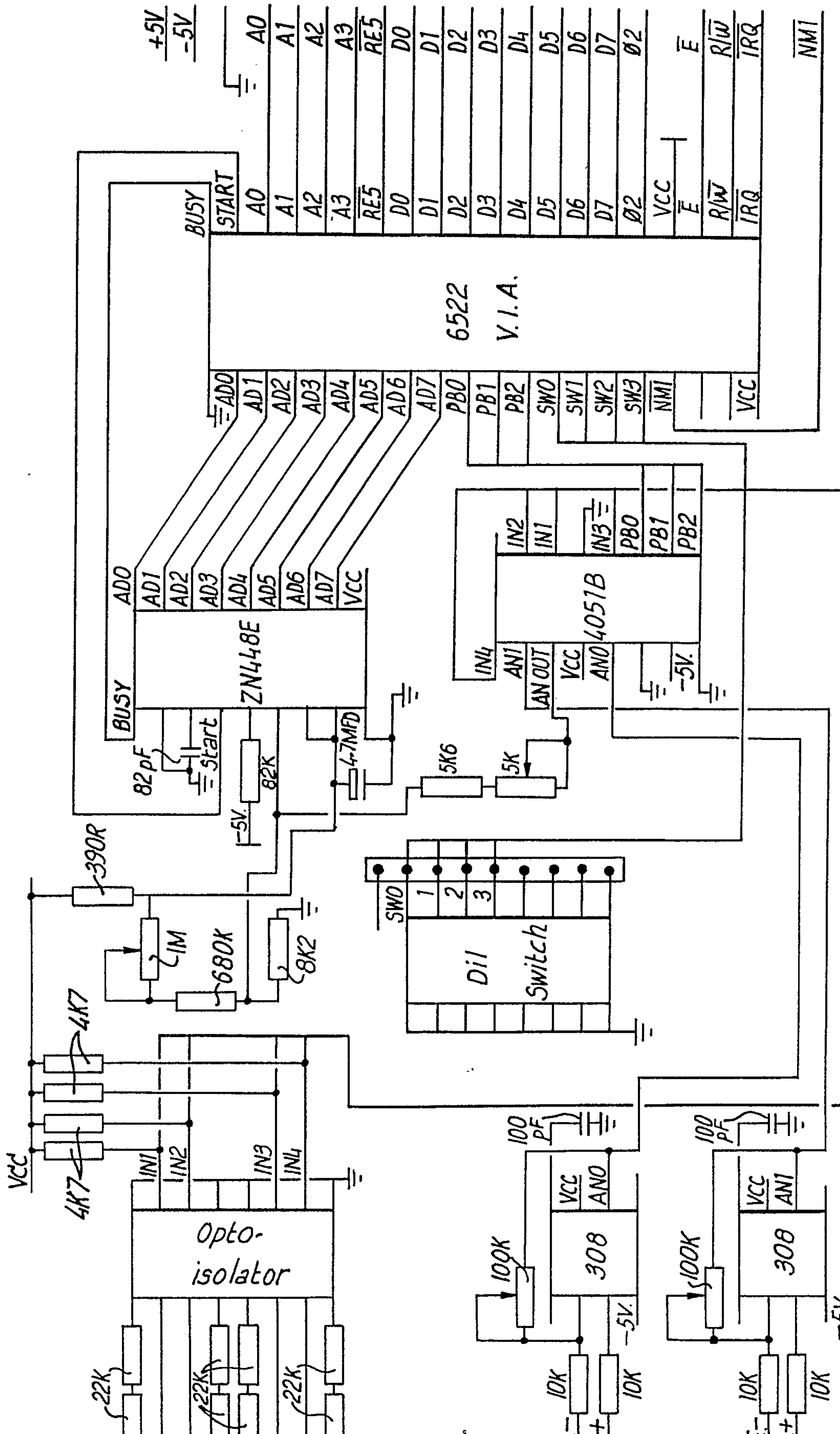

FIG. 7

SPECIFICATION

Welding apparatus

This invention relates to welding apparatus wherein a weld is effected by a pulse of electric current. Stud and spot welding are the most common forms of such technology and the invention is concerned particularly with stud welding.

Stud welding apparatus operates to weld a stud to a substrate by passing a pulse of electric current through the stud and substrate, the electrical energy being dissipated in the contact resistance between the two to heat the stud and substrate sufficient to cause localized brief melting of the materials of both. The electric current pulse is often obtained from the discharge of a capacitor, although other sources are possible.

During a welding operation a good or bad weld may occur and the quality of an individual weld will not normally be apparent visually. Testing individual welds for strength is so costly and time consuming as to be impracticable and conventional engineering statistical tests have been used, but even these are undesirable, as a test to measure the strength of a weld almost invariably involves destructive testing.

In a stud welding pulse, a graph of current against time has generally the shape shown in Fig. 3 hereof, and it is known that the shape of the graph is related to the weld quality. An electronic integrating device has been used to measure the area under the curve. However, this single factor is not a universal measure of weld quality and some bad weld conditions are not detected by this method.

Additionally, different weld properties are often required in different products. For example, maximum weld strength and the appearance of the weld can often be incompatible. The strongest welds may have sputter and flash marks and be generally ragged and untidy. This can often be acceptable for internal or functional parts, but for "show" parts requiring little strength may be unacceptable.

Similar factors affect the type of weld a user needs for other reasons, and the actual area of the pulse is not a measure of all the properties of a weld.

It is an object of the present invention to provide a method of welding and welding apparatus including improved monitoring circuitry able to indicate more accurately the quality of a weld. The invention is specifically concerned with stud welding but can be relevant to spot welding or any "pulse welding" operation wherein a pulse of electric current is passed across a junction between a workpiece and a substrate to cause localised melting.

Accordingly the invention provides a method of pulse welding wherein the welding pulse is sampled at a plurality of intervals during its duration and the measured-pulse-shape information so generated is passed to an electronic central processing unit where it is compared with desired-standard-pulse-shape information from a store, the processing unit being capable of passing a signal to an indicator to indicate whether or not the measured pulse-shape-information corresponds to the desired-standard-pulse-shape information.

The measured-pulse-shape information (referred to hereinafter simply as the "measured information") can be generated by a current measuring device as an analogue signal and converted to digital information before said comparison step.

The current measuring device can be a liner Halleffect probe disposed close to the weld point to be influenced by the magnetic field generated by the weld pulse.

The desired-pulse-shape-information (hereinafter referred to as the "standard information") will normally be stored in a memory, such as a ROM or EPROM for retrieval at each welding operation. The memory can contain standard information relating to a plurality of standard pulses desirable in different welding operations, identified and selectable for comparison purposes by the operator. The memory should have a back-up battery to avoid information loss if power is cut, and the contents can be separately stored, on tape or disc as an additional security.

Correspondence between the measured and standard information will be a property which can vary from type to type of weld and may include some or all of the following characteristics of the pulse:

i) The presence ofa first, high, peak;
ii) the tempral position of the first peak;
iii) the presence of a second, lower, peak;
iv) the temporal position of the second peak;
v) the slope of the pulse envelope at selected temporal positions;
vi) the area beneath the pulse envelope;
vii) whether or not the pulse has "gone negative"; and
viii) the temporal separation of the rising and falling slopes of the pulse at different current values; (ie the "width" of the pulse.

The characteristics selected to be tested for correspondence will depend on the type of weld desired and the criteria will usually be associated with a particular standard pulse. Information identifying the nature of the "correspondence" can be stored in the memory with the standard information and released after each weld to programme the CPU to effect the comparison accordingly.

"Correspondence" will normally be expressed as a percentage, ie a weld which has a measured characteristic within a specified tolerance, say 5%, of the standard characteristic will be deemed acceptable.

Detection of an unacceptable characteristic will result in an indication being given by visual or audible means or both. The operator or an automatic sorter on a production line will then separately store the unacceptably identified welded article for testing, inspection or rejection as desired. The CPU can be connected to a printer to print out all the pulse characteristics of the suspect weld, or only the suspect characteristics for further decision or study.

A large number of samplings per pulse is desirable and in a 5 millisecond pulse a minimum of one hundred samplings is just acceptable. However, 500 is currently attainable and faster devices allowing a higher rate are being sought as they would be superior.

The apparatus preferably has a low-current threshold below which properties are disregarded, as transients and variations always occur in this region without affecting the weld quality.

The invention includes stud welding apparatus constructed and designed to operate in accordance with the above method steps.

The invention will be described further, by way of example, with reference to the accompanying drawings, wherein:

Fig. 1 is a schematic illustration of a stud welding operation before welding;

Fig. 2 is a view of a stud weld completed;

Fig. 3 is a graph showing a typical "good" stud weld current/time pulse;

Figs. 4 and 5 are comparable graphs showing "bad" welds;

Fig. 6 is a block diagram of sensing and monitoring devices; and

Fig. 7 is a circuit diagram of an analogue/digital connector used in the devices of Fig. 6.

A preferred apparatus and method of the invention are used in a stud welding set up generally of the form shown in Fig. 1, wherein a stud 10 is urged by means not shown into contact with a substrate 11. A current pulse from a charged capacitor 12 passes through lines 13 upon closure of a welding switch 14. The contact resistance between the stud 10 and substrate 11 dissipates the electrical pulse energy as localized heat which melts the metal of the stud and substrate eventually to form a body 15 of weld metal uniting the stud 10 and substrate 11.

The pulse shape of a good weld is shown in Fig. 3 and can be observed in practice using a C.R.O. It will be seen that the curve has several distinctive characteristics as follows:

a) a rapid rise 16 to maximum current at a first peak 17, due to the cool metal adjacent the contact point having a low resistance which rises as it heats up;

b) a fall 18 to a trough before a second peak 19 which occurs as the stud tip 20 melts and increases the contact area; and

c) a gradual fall 21 to a zero value.

A low current threshold is set at the level of the dotted horizontal line. Below this threshold transient and variable phenomena occur in all welds and comparisons are not meaningful. Thus the lower part of the pulse is ignored for checking purposes.

Figs. 4 and 5 illustrate graphs which obtain when a poor weld has been made. In particular Fig. 4 shows a graph wherein a stud with no pip has been used, Fig. 5 when an incomplete pip has been present. Both these cures represent welds which are weak or non-existent. Graphs 4 and 5 are only illustrative and the practitioner skilled in the art will be able to generate and identify many other undesirable graph forms.

In the preferred method and apparatus of the invention (Fig. 6) a linear Hall-effect probe 21 is disposed near the weld point and generates an analogue output signal which is dependent upon the magnetic field generated by the weld pulse which is dependent upon the pulse current at any instant. The analogue output is cleaned at 22, amplified at 23 and passed through a multiplexer 24, amplifier 25 and a cleaning filter 26 to an 8-bit analogue-to-digital converter 27 whose output is passed to a holding store 28 connected to a processor 29 (this is a Rockwell 6502 CPU). The circuitry prior to the store 28 has a conversion time of $10\mu s$(determined currently by the A/D convertor) which allow the pulse current to be sample 500 times during a 5 millisecond pulse. A second store 30 is connected to CPU and has a back-up battery power supply 31.

The CPU compares the measured information from store 28 with the standard information from store 30 which can be a RAM, ROM or EPROM holding several selectable sets of standard information. Comparison can start as soon as information arrives at store 28 but will not normally be finished at the end of the weld pulse. The interval between weld pulses (certainly seconds long and sometimes minutes long) is used to complete the comparison according to a programme compatible with the type of standard stored and the type of weld needed. As has been previously mentioned, a very strong weld may have a pulse shape different from that of a good looking clean weld and the user will select the desired properties in accordance with the application.

If the measured pulse differs from the standard pulse by more than a set tolerance the C.P.U. will activate a display, (visual or audible) to alert the operater or to actuate a rejection device on an automatic or robot-controlled production line. The CPU can further activate a recordal of a "bad" curve on a printer or like device for further analysis. If a succession of "bad" welds is sensed an automatic line can be halted for investigation as to any variance in desired starting conditions such as stud properties and substrate and/or stud cleanliness.

The invention provides a method of and

apparatus for stud welding which enables effective 100% weld testing with opportunity to test doubtful welds for suitability. Manufacturing quality can be greatly enhanced with no delay and minimal additional cost or complication. The invention has been described specifically in relation to stud welding but can be applied, with appropriate modification to other pulse welding operations such as spot welding.

CLAIMS

1. A method of pulse welding wherein a welding pulse is sampled at a plurality of intervals during its duration and the measured-pulse-shape information so generated is passed to an electronic central processing unit where it is compared with desired-standard-pulse-shape information from a store, the processing unit being capable of passing a signal to an indicator to indicate whether or not the measured pulse-shape-information corresponds to the desired-standard-pulse-shape information.

2. A method as claimed in claim 1, wherein the measured-pulse-shape information (referred to hereinafter simply as the "measured information") is generated by a current measuring device.

3. A method as claimed in claim 2 wherein the measured information is generated as an analogue signal and converted to digital form before said comparison step.

4. A method as claimed in claim 1, 2 or 3 wherein the current measuring device is a Hall-effect probe disposed close the the weld point to be influenced by the magnetic field generated by the weld pulse.

5. A method as claimed in claim 4 wherein a linear Hall-effect probe is used.

6. A method as claimed in any preceding claim, wherein the desired-pulse-shape-information (hereinafter referred to as the "standard information" is stored in a memory (such as a ROM or EPROM) for retrieval at each welding operation.

7. A method as claimed in claim 5, wherein the memory is a ROM or EPROM.

8. A method as claimed in claim 6 or 7 wherein the memory contains standard information relating to a plurality of standard pulses desirable in different welding operations, identified and selectable for comparison purposes by the operator.

9. A method as claimed in claim 6, 7 or 8 wherein the memory has a back-up power supply to avoid information loss if power is cut.

10. A method as claimed in any of claims 6 to 9 wherein the contents of the memory are separately stored, on tape or disc.

11. A method as claimed in any preceding claim wherein correspondence between the measured and standard information is determined using selected ones of the following characteristics of the weld pulse:

i) The presence of a first, high, peak;
ii) the temporal position of the first peak;
iii) the presence of a second, lower, peak;
iv) the temporal position of the second peak;
v) the slope of the pulse envelope at selected temporal positions;
vi) the area beneath the pulse envelope;
vii) whether or not the pulse has "gone negative"; and
viii) the temporal separation of the rising and falling slopes of the pulse at different current values, (ie the "width" of the pulse.

12. A method as claimed in claim 11 wherein information identifying the nature of the "correspondence" can be stored in the memory with the standard information and released after each weld to programme the CPU to effect the comparison accordingly.

13. A method as claimed in claim 11 or 12 wherein a "correspondence" is expressed as a percentage.

14. A method as claimed in any preceding claim wherein detection of an unacceptable characteristic results in an indication being given by visual or audible means or both.

15. A method as claimed in claim 14 wherein an automatic sorter on a production line separately stores an unacceptably-identified welded article for testing, inspection or rejection as desired.

16. A method as claimed in any preceding claim wherein the CPU is connected to a printer to print out all the pulse characteristics of the suspect weld, or only the suspect characteristics for further decision or study.

17. A method as claimed in any preceding claim, wherein in a 5 millisecond pulse one hundred or more samplings are made.

18. A method as claimed in claim 17, wherein 500 or more samplings are made.

19. A method as claimed in any preceding claim wherein a low-current threshold is provided below which properties are disregarded.

20. A method of pulse welding substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

21. Stud welding apparatus constructed and designed to operate in accordance with any one of the preceding claims.

22. Stud welding apparatus substantially as hereinbefore described with reference to the accompanying drawings.

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