# DEVELOPMENT OF P.C. BASED WELD MONITORING SYSTEM FOR FLASH BUTT WELDING OF ECONOMISER TUBES

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## INTRODUCTION

Flash butt welding is used extensively for welding of steel for different applications ranging from rails to automobile wheels in our country. Although this process is widely used for past six decades, there is still apprehension in adaptation of this process in certain critical applications for want of proper reliable N.D.T. method or proper quality assurance method. The present work addresses this problem of reliable N.D.T. method by suggesting the adaptation of computer based parameter monitoring system for checking every production joint. The first part of the work discusses the development of a P.C. based weld monitoring system. The second part of the work discusses the evaluation of the performance of the developed monitoring system in the actual production environment by welding economiser tube joints.

### Objectives of the present programme

(a) To develop a P.C. based flash butt welding monitoring system for measurement of various parameters such as number of pre heat cycles, flashing distance, flashing voltage etc., which can be adopted to any butt welding machine.

(b) To determine the minimum and maximum range of various measured parameters through the developed system by systematic experimentation.

(c) To establish the control limits for each of these parameters for actual production of economiser tube welded panels.

### Development of a P.C. based flash butt welding parameter monitoring system

Based on the earlier experience gained by graphic recording of process parameters such as voltage, current and movement as a function of time during welding, through a strip chart recorder, it is conceived to collect data on the following parameters for every weld joints[1-3];

1. No. of preheat cycles
2. Preheat travel in mm
3. Preheat current on time
4. Preheat current off time
5. Flashing speed
6. Flashing distance
7. Flashing average voltage
8. Flashing average current
9. Upset distance
10. Upset average current
11. Upset speed
12. Upset average voltage
13. Total travel

These parameters are chosen as per the guide lines given in the standard specification on flash butt welding of economiser tubes[4].

For the computation of above parameters, it is essential to have the information on voltage, current and movement for every instant during the entire process cycle[5]. The first part of the development work involves the mounting of transducers for measurement of current, voltage and movement in the machine. For the measurement of secondary current in Kiloamperes, a toroid coil was mounted in the secondary of the welding machine and the output was given to an integrator, filter and amplifier card to get a d.c.voltage of 0 - 5 V. For the measurement of voltage, the secondary voltage is sensed by a pair of shield cables in the two clamps and the output is processed by filter, rectifier and amplifier circuits to get 0-5 V D.C. For the measurement of the movement, an L.V.D.T. of 50 mm range was used and mounted on the fixed platen of the machine. The moving plunger of the L.V.D.T. is connected to the movable platen in the weld machine. The output from the L. V. D. T. is processed by a 5 kHz carrier frequency amplifier circuitry to produce a D.C. output from 0 - 5 V in proportion to the movement of the platen. The calibration of the secondary current in kilo amperes is carried out by means of a standard current measuring device (0 - 99 kA) developed by WRI. The voltage was calibrated by using the precision digital voltmeter. The L.V.D.T. is calibrated by using a vernier height gauge.

An Intel 8088 CPU board working in standard P.C. bus with a 12 bit analog to digital card was used to digitise the analog inputs (0 - 5 V D.C. range) from the three circuits discussed earlier. The digitised data on three parameters viz. current, voltage, movement are all stored in the 64K memory of the board. Further, the entire digitised data are processed by 8088 CPU unit in the system to compute the various parameters and display in the panel adjacent to the machine. The display contains a 20 character alphanumeric fluorescent display and set of L.E.D. 's to indicate whether the computed parameters are well within the limits programmed or not by green or red light indication. The entire unit is assembled in a standard cubicle and kept near the welding machine. There is a RS-485 interface in the unit so that a personal computer (IBM PC / AT 386 system with 4 MB memory) can be hooked at a remote place to this control unit. The block diagram of the developed system is shown in **fig.-1.**

At the P.C. end, a windows based software receives the flash welding parameters from the main unit in the machine and stores each joint parameters with the file name containing date and time of welding as shown in **fig.-2**.

It is possible to get the hard copy of graphic recordings of the current, voltage and movement from the stored data on every joint in the P. C. as shown in **fig.-3**.

Further, it is possible to get a table of values of parameters for the all the joints made in particular shift with status of joint as "good" or "bad". For each joint, the "good" or "bad" status is arrived based on the adherence or non adherence to the limits of the values of the computed parameters as shown in **fig.-4**.

### Evaluation of the monitoring system

For the evaluation of the monitoring system, the first stage of experimentation was carried out by deliberately varying the machine settings and correlating the measured parameters from the computer to the mechanical strength of the joint. The second

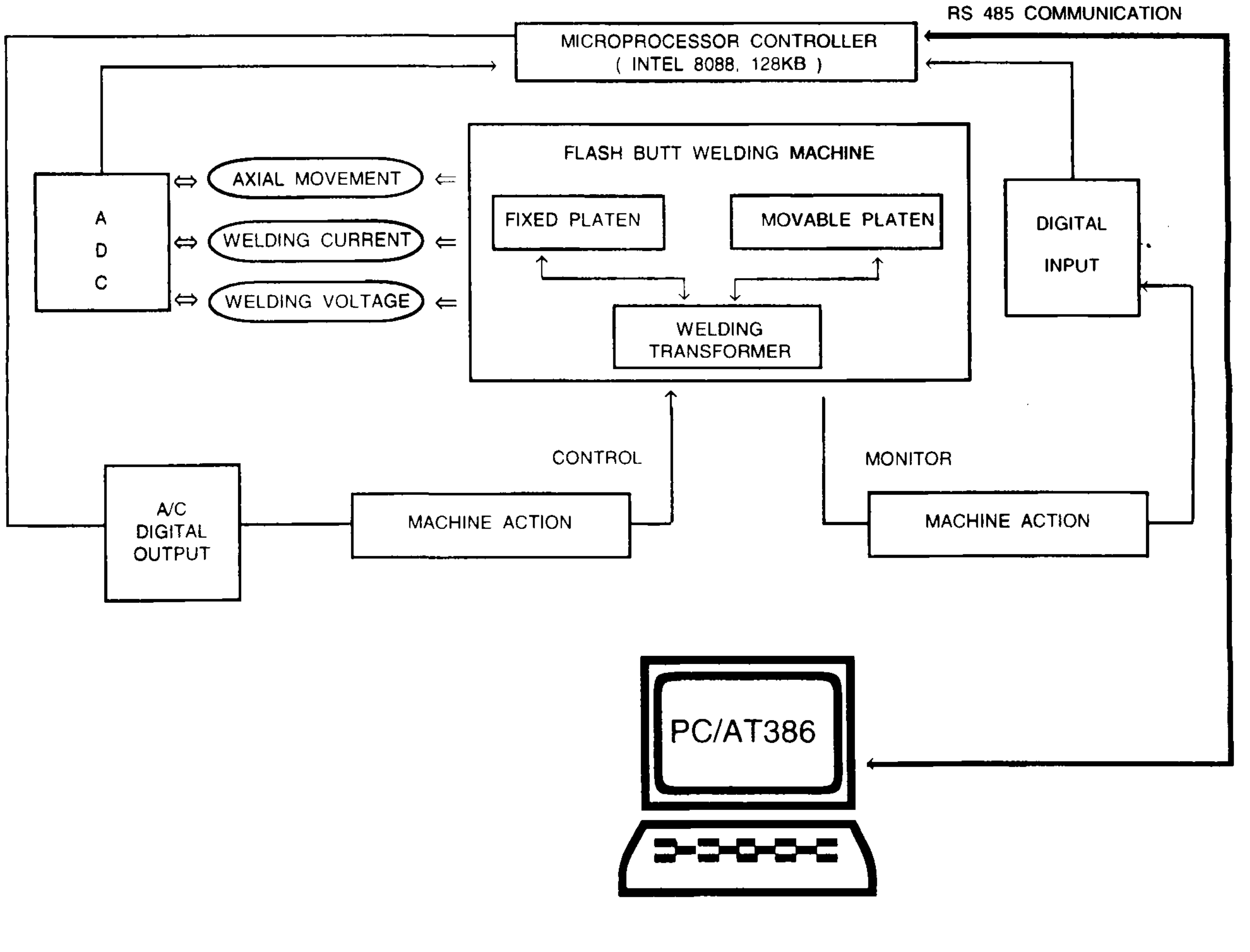


*Fig. 1 Block diagram of the flash butt weld monitoring system*

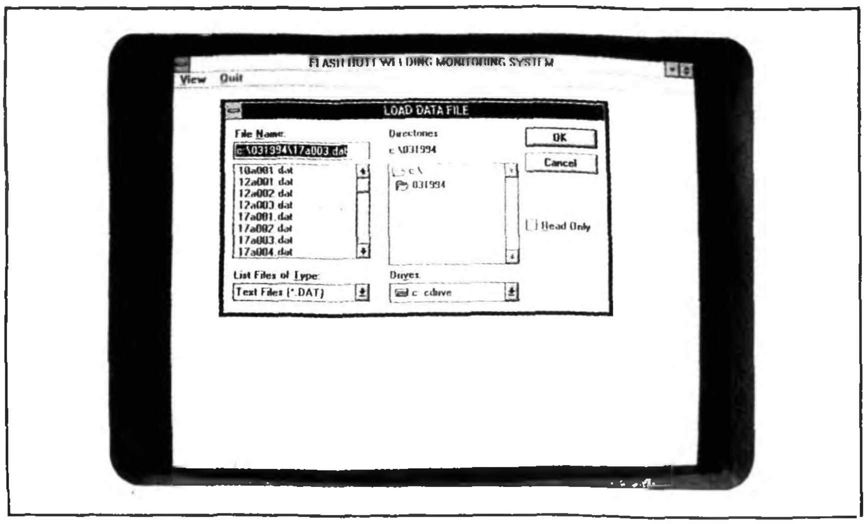


*Fig 2 Screen showing the data files containing weld parameters for each joint.*

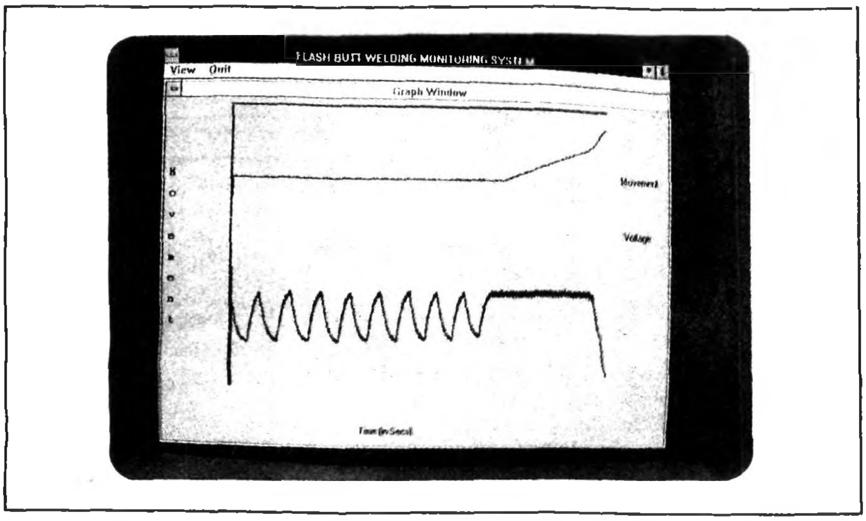


*Fig. 3 Screen showing graphical recording of weld parameters for a typical joint.*

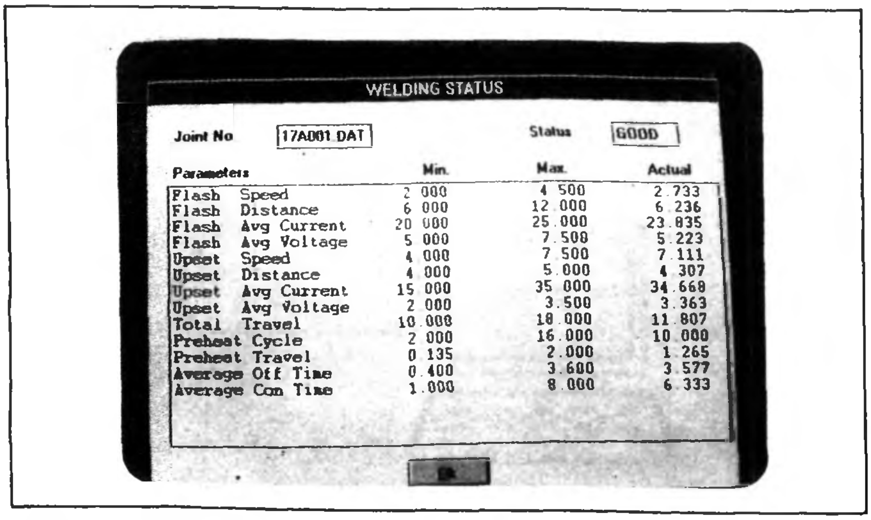


*Fig 4 Screen showing status of weld parameters for a typical joint.*

stage of the experimentation involved measuring the actual values of the measured parameters for 20 production joints for a particular established welding condition and to determine the control limits. The developed system is interfaced to a 150 kVA capacity flash butt welding machine. Low carbon steel tube (SA 210 Gr. A) of diameter 44.5 mm and thickness 4.5 mm was chosen for experimentation.

### Correlation of measured parameters and bend test results

Initial experimentation was carried out with a view to establish the correlation between the computed parameters and mechanical strength of the joint. For strength assessment of the tube joint, 180° bend test with 3 't' former radius was used. Three critical factors namely flashing speed, flashing distance and secondary voltage were chosen for $2^3$ factorial design of experimentation and each of the factors was varied at 2 levels. For all the trials, parameters were computed and stored in the developed system. The results for the experimentation is summarised in table-1. In the table'+' means higher level of the parameter is used and '-' means lower level of parameter is used.

From the table-1, it is found that the effect of preheat parameters on the bend test result seems to be significant, For trial No.2, the welded specimen failed in bend test and it was found the number of preheat cycle is the lowest. Further, the secondary voltage and flashing distance are again on the lower side. The failure of the specimen No.2 can be explained as follows with less number of preheat cycles, the extent of preheating is less and, therefore, extent of volumetric heating adjacent to the faying surface is limited. Further, in this case, less flashing voltage and distance, would have promoted lesser heat generation during flashing stage also. With the inadequate and flashing, the consolidation of the joint during upsetting is poor and failed during bend test.

The effect of the three factors on the computer parameters can again be seen from the **table-1.** As the secondary voltage of the transformer is increased, it is found the number of preheat cycles came down 10 to as low as 2. The average preheat on time and off time does not show any significant variation. Flashing voltage showed an increasing from 5.2 V to 7.3 V.

The upset speed increase with reduction of secondary voltage setting.

Flashing speed does not show significant variation in the measured parameters. It is evident from the above observations, that the secondary voltage has got the significant effect on the strength of the joint and it is reflected in the variation of measured parameters such as number of preheat cycles, upset speed etc. However, it is essential to establish tolerance limits of the each of measured parameters, in order to ensure the strength of the joint. For this purpose, it is essential to know the scatter of each of the measured parameters in the actual production environment. This is being attempted in next part of the work.

**Establishment of control limits for computed parameters**

In this part of the work, the scatter in the computers was evaluated by compiling the measured parameters for 20 flash butt welded joints for same materials at different timings. Those values are summarised in table-2. The mean and standard deviation for each of the measured parameters were computed for this table of values and those are presented in table - 2. Subsequently, minimum and maximum limit of the parameters were derived from the table of values by taking ± 3σ as range of variation as shown in table - 3 **for flash butt welding of the low** carbon steel tube of Ø 44.5 X 4.5 mm.

**CONCLUSIONS**

Based on the present work carried out on flash butt welding with the developed monitoring system, the following conclusions can be drawn.

(a) A computer based monitoring system is successfully developed for monitoring process parameters during flash butt welding and retrofitted for use in economizer tube welding.

**TABLE -1. RESULTS FROM STATISTICAL DESIGN OF EXPERIMENTS**

| Joint | Machine settings | | | Bend test |
|---|---|---|---|---|
| no | Flash dist. | Flash speed | Flash volt. | |
| 1 | - | + | - | OK |
| 2 | - | - | + | N.OK |
| 3 | - | - | - | OK |
| 4 | + | + | + | OK |
| 5 | + | + | - | OK |
| 6 | + | - | + | OK |
| 7 | + | - | - | OK |
| 8 | - | + | + | OK |

| Sl. no. | Pre heat cycle | Pre heat travel mm | Avg. Off time sec | Avg. On time sec | Flash speed mm / sec | Flash dist. mm | Flash avg. ct. kA | Flash avg. vol. V | Upset speed mm/ sec | Upset dist. mm | Upset avg. ct. kA | Upset avg. vol. V | Total travel mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | 1.27 | 0.4 | 1.08 | 2.65 | 5.40 | 24.0 | 5.2 | 6.30 | 5.32 | 31.4 | 3.88 | 11.9 |
| 2 | 2 | 1.71 | 0.4 | 1.34 | 2.10 | 5.97 | 23.4 | 7.3 | 4.50 | 5.40 | 25.8 | 3.81 | 13.1 |
| 3 | 9 | 0.29 | 0.4 | 1.10 | 2.23 | 7.53 | 23.4 | 5.2 | 5.73 | 5.48 | 26.1 | 3.36 | 13.3 |
| 4 | 3 | 1.94 | 0.3 | 1.07 | 2.95 | 9.82 | 23.9 | 7.3 | 4.89 | 5.61 | 20.7 | 3.37 | 17.4 |
| 5 | 7 | 0.59 | 0.4 | 1.1 | 2.63 | 10.44 | 24.6 | 5.2 | 5.64 | 5.55 | 30.5 | 3.54 | 16.5 |
| 6 | 2 | 0.14 | 0.2 | 0.91 | 2.33 | 11.10 | 24.1 | 7.4 | 4.88 | 5.72 | 29.4 | 3.94 | 16.6 |
| 7 | 8 | 0.25 | 0.4 | 1.12 | 2.32 | 11.32 | 20.7 | 5.3 | 6.70 | 5.51 | 31.0 | 3.66 | 17.1 |
| 8 | 3 | 0.31 | 0.4 | 1.04 | 2.67 | 6.68 | 27.7 | 7.1 | 5.39 | 5.46 | 28.4 | 3.55 | 12.5 |

**TABLE 2. STANDARD DEVIATION DURING PRODUCTION JOINTS (REF.6)**

| Joint No. | Pre-heat cycle | Pre heat travel | Avg. off time sec | Avg. on time sec | Flash butt mm/sec | Flash dist. mm | Flash avg. ct. kA | Flash avg. volt V | Upset speed mm.sec | Upset dist. mm | Upset avg. ct. kA | Upset avg. volt V | Total travel mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8 | 0.88 | 0.49 | 1.25 | 2.44 | 6.64 | 22.52 | 5.39 | 6.47 | 5.65 | 24.57 | 3.43 | 13.18 |
| 2 | 7 | 1.04 | 0.49 | 1.28 | 2.35 | 6.00 | 23.88 | 5.40 | 5.72 | 5.80 | 27.8 | 3.52 | 12.85 |
| 3 | 10 | 0.45 | 0.48 | 1.19 | 2.44 | 7.16 | 20.62 | 5.45 | 6.71 | 5.57 | 24.42 | 3.56 | 13.18 |
| 4 | 8 | 0.32 | 0.46 | 1.16 | 2.30 | 6.78 | 21.95 | 5.54 | 4.54 | 6.01 | 21.71 | 2.71 | 13.09 |
| 5 | 4 | 2.23 | 0.48 | 1.37 | 2.37 | 4.88 | 26.70 | 5.42 | 5.79 | 5.55 | 33.38 | 3.66 | 12.66 |
| 6 | 7 | 2.21 | 0.49 | 1.36 | 2.35 | 4.87 | 23.64 | 5.59 | 6.18 | 5.55 | 21.71 | 3.34 | 13.34 |
| 7 | 7 | 0.92 | 0.49 | 1.26 | 2.33 | 6.33 | 24.72 | 5.61 | 5.55 | 5.55 | 27.34 | 3.54 | 12.81 |
| 8 | 5 | 2.43 | 0.43 | 1.34 | 2.32 | 4.78 | 25.33 | 5.48 | 6.35 | 4.98 | 35.16 | 4.07 | 12.20 |
| 9 | 6 | 1.24 | 0.42 | 1.17 | 2.55 | 6.77 | 33.07 | 5.58 | 5.43 | 5.50 | 20.28 | 2.65 | 13.51 |
| 10 | 6 | 0.91 | 0.45 | 1.18 | 2.36 | 6.31 | 24.90 | 5.61 | 6.17 | 5.49 | 29.80 | 3.77 | 12.70 |
| 11 | 7 | 1.47 | 0.45 | 1.30 | 2.39 | 6.32 | 26.51 | 5.65 | 6.43 | 5.17 | 32.33 | 3.88 | 12.66 |
| 12 | 5 | 0.41 | 0.45 | 1.16 | 2.35 | 6.83 | 27.29 | 5.61 | 6.07 | 4.77 | 38.44 | 4.23 | 12.03 |
| 13 | 8 | 1.18 | 0.47 | 1.44 | 2.26 | 5.27 | 24.85 | 5.61 | 4.17 | 5.95 | 21.34 | 2.63 | 13.01 |
| 14 | 6 | 2.22 | 0.45 | 1.25 | 2.37 | 5.24 | 24.55 | 5.46 | 6.21 | 5.58 | 29.19 | 3.63 | 12.96 |
| 15 | 5 | 0.88 | 0.46 | 1.18 | 2.37 | 6.44 | 27.21 | 5.49 | 5.92 | 5.33 | 29.74 | 3.73 | 12.66 |
| 16 | 6 | 2.24 | 0.44 | 1.24 | 2.90 | 4.67 | 24.61 | 5.60 | 5.09 | 5.79 | 27.35 | 3.37 | 12.71 |
| 17 | 5 | 1.12 | 0.46 | 1.22 | 2.90 | 5.92 | 26.49 | 5.45 | 6.03 | 5.08 | 37.16 | 4.03 | 12.13 |
| 18 | 6 | 2.16 | 0.47 | 1.26 | 2.41 | 5.37 | 22.78 | 5.39 | 6.58 | 5.48 | 29.19 | 3.66 | 13.01 |
| 19 | 8 | 0.63 | 0.44 | 1.13 | 2.60 | 6.69 | 27.02 | 5.46 | 5.98 | 5.74 | 26.47 | 3.49 | 13.07 |
| 20 | 5 | 1.08 | 0.47 | 1.20 | 2.63 | 6.52 | 26.47 | 5.37 | 5.19 | 5.47 | 24.40 | 2.97 | 13.08 |
| Mean | 6.5 | 1.32 | 0.46 | 1.23 | 2.39 | 5.99 | 25.40 | 5.61 | 5.83 | 5.50 | 28.03 | 3.49 | 12.84 |
| Std. Davi | 1.5 | 0.76 | 0.02 | 0.07 | 0.10 | 0.80 | 02.61 | 0.08 | 0.66 | 0.31 | 5.25 | 0.45 | 00.39 |

**TABLE - 3. TABULATION OF MINIMUM / MAXIMUM RANGE FOR COMPUTED PARAMETERS. (REF. 6)**

| setup parameter | Mean value | Standard deviation | Standard deviation (%) | Minimum range | Maximum range |
|---|---|---|---|---|---|
| 1. Preheat cycle | 6.45 | 1.47 | `22.74 | 3.00 | 10.00 |
| 2. Preheat travel | 1.32 | 0.76 | 57.48 | 0.13 | 2.50 |
| 3. Average current off time | 0.63 | 0.55 | 87.88 | 0.24 | 0.50 |
| 4. Average current on time | 1.37 | 0.46 | 33.75 | 0.90 | 1.50 |
| 5. Flashing speed | 2.39 | 0.01 | 4.18 | 2.20 | 3.00 |
| 6. Flashing distance | 5.99 | 0.81 | 13.37 | 5.00 | 12.00 |
| 7. Flash average current | 25.40 | 2.61 | 10.28 | 20.00 | 28.00 |
| 8. Flash average voltage | 5.51 | 0.08 | 1.57 | 5.20 | 7.40 |
| 9. Upset speed | 5.83 | 0.67 | 11.47 | 4.50 | 6.80 |
| 10. Upset distance | 5.50 | 0.31 | 5.67 | 5.00 | 6.00 |
| 11. Upset average current | 28.09 | 5.25 | 18.70 | 20.00 | 40.00 |
| 12. Upset average voltage | 3.49 | 0.45 | 12.84 | 2.70 | 4.30 |
| 13. Total travel | 12.84 | 0.39 | 3.02 | 11.00 | 18.00 |

(b) The methodology for establishing the control limits of the measured parameters for flash butt welding of Ø 44.5 x 4.5 mm is demonstrated.


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### REFERENCES


1. K. Asokkumar, KGK Murti, VR. Samuel, V. Rabindran, Development of Monitors for resistance, friction and induction pressure welding, Proc. of conf. on welding, Department of science and technology, New Delhi, 1990.
2. V. Ravindran, k. Asokkumar, KGK Murti, VR. Samuel, In process monitoring system for flash butt welding machine of economiser tubes, Proc. of national welding seminar, 1992, Bombay.
3. K. Asokkumar, KGK Murti, VR. Samuel, V. Ravindran, Role of decarburised zone formation in flash butt welding of carbon steel, proc. of national welding Seminar, Bhilai, 1993.
4. BS 4204 : 1989, British standard specification for flash welding of steel tubes for pressure applications
5. Prof. J. Ruge and Dr. C. Kohl, Computerised process control and temperature calculation in flash welding, Scweissen and schneiden, Jan., 1986, E-8.
6. A Chandraprakash : Evaluation of flash butt welding using computer monitoring system. ME welding thesis submitted in Karnataka university, 1994.