

ray tube, shown on the top, produces collimated radiation, which penetrates the material. The modulated x-ray field is acquired using an image intensifier and a video camera at 30 frames per second. The image is digitized by the image processing board and processed by computer. X-ray shutters are used to reduce radiographic noise.

The arc force measurement apparatus consists of force sensor (a digital scale), balance beam, pivot, bearing agate and pivot supporters, as shown in Fig. 2 for the measurement of both the arc force and electromagnetic force, and in Fig. 3 for the measurement of electromagnetic force alone (no welding arc). The workpiece was placed at one end of the beam and the balance weight at the other end to prevent scale overload. A photograph of the experimental arrangement is shown in Fig. 4. The digital scale is at the left and the welding torches are at the right.

The balance beam is made of a hollow square aluminum bar about one meter long. Aluminum was used because it is light and nonmagnetic. The pivot is made of stainless steel with a sharp knife edge at one end, the other end being circular. The pivot is mounted on the balance beam approximately in the middle. The balance beam with the sharp knife edge of the pivot sits on the bearing agate, which is a hard stone. The sharp edge used reduced the friction force between the pivot and the pivot supporter.

Processing of Data for Force Measurement

The balance weight, which is positioned on the right side of the balance beam (Fig. 2), was selected to produce a positive net force on the digital scale, about 50 to 100 g. During welding, the net force measured by the digital scale decreased because of the arc and electromagnetic forces which acted on the left side of the balance beam. When presenting these data, we plotted the actual welding force acting on the left end of the balance beam.

The scale was set to continuous output data mode. The force readout from the scale was fed to the computer in digital format through the RS232 serial port — Fig. 2. The scale precision is 0.01 g. Each set of data consists of 6 bytes. A 6-digit hexadecimal value is obtained from the least-significant nibble of each byte. A computer program converts the hexadecimal value to a decimal value that corresponds to the actual force. The force data acquisition rate on the scale is about 4 to 5 data points per second, limited by the internal averaging mechanism built into the scale. Including the

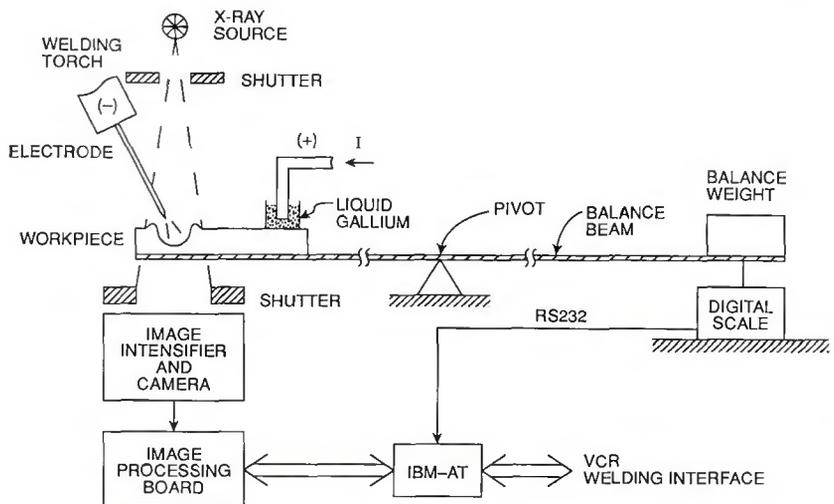


Fig. 2 — Schematic of the experimental apparatus for simultaneous measurement of arc force and pool depression.

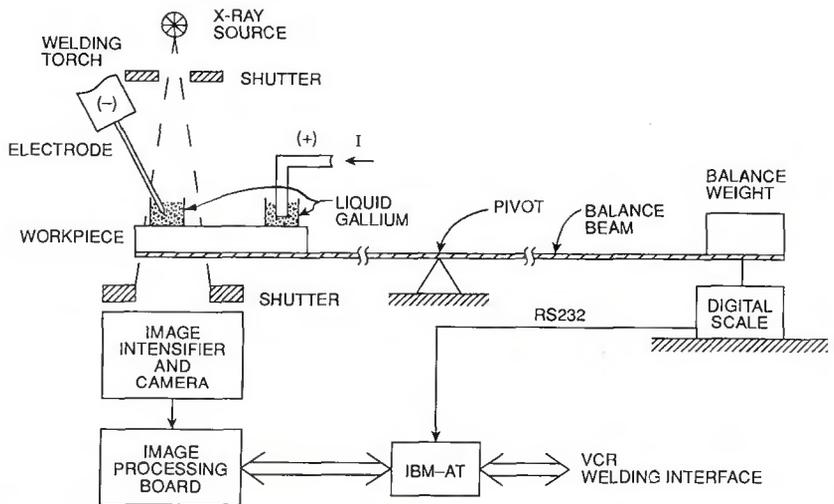


Fig. 3 — Schematic of the arrangement for reference measurements (electromagnetic force measurement).

Fig. 4 — Photograph of the balanced force measurement device. Digital scale is at left, and welding torches are at right.

