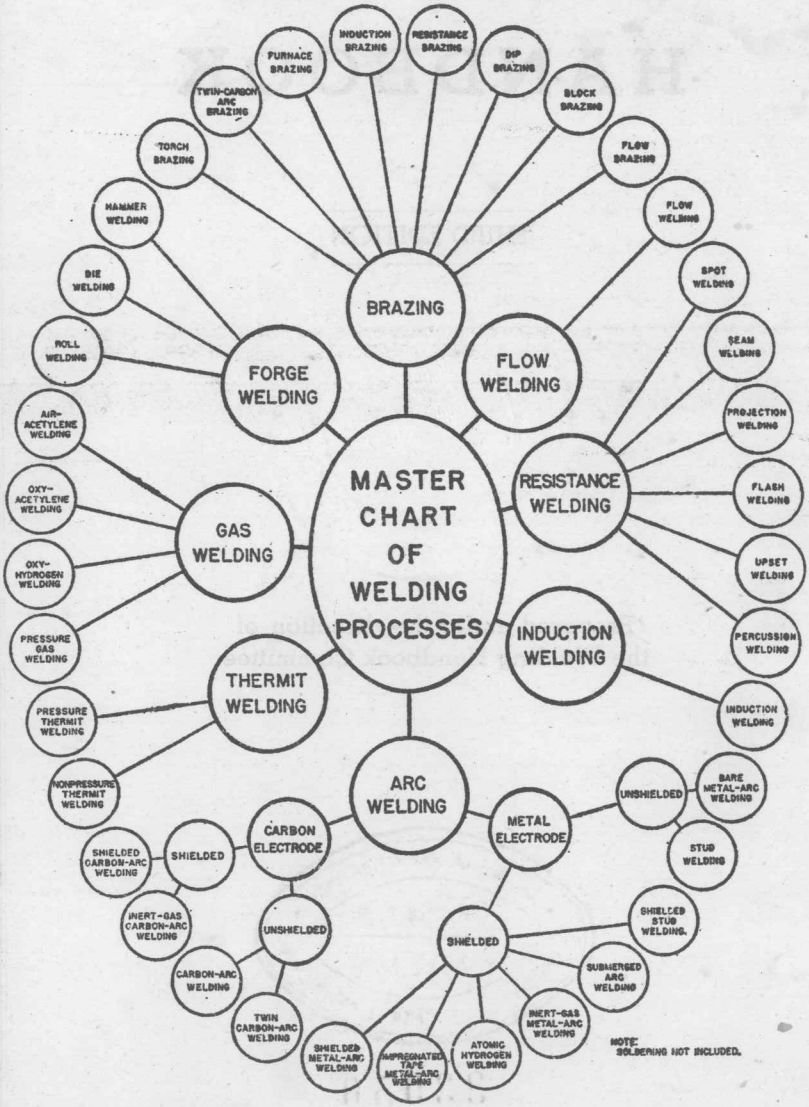
WELDING HANDBOOK

THIRD EDITION

Prepared under the direction of
the Welding Handbook Committee

1950

WELDING METHODS AND PROCESSES



PREFACE

THE WELDING HANDBOOK is recognized throughout the world as a source of authoritative information. In preparing the Third Edition, no effort was spared to maintain the reputation established by the earlier editions. The Third Edition of the WELDING HANDBOOK contains information on welding in all its aspects, based on recognized practices in industry at the time of its issuance.

To make it more useful the arrangement of information in the Third Edition differs from that in the 1942 Edition based on suggestions received from HANDBOOK users in the course of a nationwide survey; the following brief remarks on these differences may assist the reader in securing maximum benefit from this HANDBOOK.

The individual chapters are arranged in groups, principally by processes, materials and applications. The material contained in each chapter in a given group is arranged in the same general order and under the same major headings in so far as possible. Thus a reader who has acquired familiarity with the contents of one chapter may expect to find the same types of information in the same relative locations in any other chapter within the same group.

Because of the many new welding developments and applications since 1942, it was necessary to include a considerable amount of information that was not in previous editions of the HANDBOOK. To accomplish this without making the book too large for frequent use, the text is set in two columns instead of one, and in so far as possible, data are given in tables instead of in the text; these tables make the HANDBOOK more useful for ready reference. Space is further saved by including cross references in each chapter to related information in other chapters thus avoiding repetition. Ease of finding information is further enhanced by an enlarged index.

Recognizing the impossibility of including all information on every subject within the limits of a single book, a bibliography is included at the end of each chapter listing the more important technical articles and books as well as applicable codes, standards and specifications published on the subject of that chapter.

A complete chapter is devoted to general engineering tables, which were selected to satisfy the need for such data in both the shop and the office.

Even with all of the foregoing changes much of the information contained in the Third Edition was drawn from the 1942 Edition, with revisions made as necessary to bring it up to date. Although the authors who contributed to the 1942 Edition are not listed, their indirect contributions to the Third Edition are gratefully acknowledged.

It would have been impossible to prepare the Third Edition without the generous contributions of time and effort of the members of the chapter committees, whose names are shown at the beginnings of the chapters and in the Index of Authors at the back of the HANDBOOK. Appreciation is also expressed to the companies with

which these members are affiliated for their understanding of the need for these contributions and the tolerance with which they accepted interruptions in company business so that this HANDBOOK could be published

Particular appreciation is extended to the members of the WELDING HANDBOOK Committee who not only planned each step so that the Third Edition would be as useful as possible, but who read each chapter carefully and through many revisions.

Very special acknowledgment is due to Mr. H. C. Boardman, for whom, as chairman of the WELDING HANDBOOK Committee, preparation of the Third Edition became a responsibility never to be forgotten, and who by his tireless and conscientious effort inspired all other committee members.

While this HANDBOOK is intended primarily to serve as a source of information for engineers in the design, fabrication and inspection of welded construction it should prove useful to anyone seeking information on welding; the text is sufficiently extensive to make it useful as an engineering textbook.

The Third Edition of the WELDING HANDBOOK is presented as a tribute to the members of the AMERICAN WELDING SOCIETY and the welding industry which they represent. It is dedicated to meeting their needs with the hope that it will serve this purpose well.

SIMON A. GREENBERG, *Editor*

January 1950

TABLE OF CONTENTS

CHAPTER 1

STANDARD WELDING TERMS AND THEIR DEFINITIONS*†

A

Actual Throat: See Throat of a Fillet Weld.

Air-Acetylene Welding: A gas-welding process wherein coalescence is produced by heating with a gas flame or flames obtained from the combustion of acetylene with air, without the application of pressure and with or without the use of filler metal.

All-Weld-Metal Test Specimen: A test specimen wherein the portion being tested is composed wholly of weld metal.

Angle of Bevel: See Bevel Angle.

Arc Brazing: See Twin-Carbon Arc Brazing.

Arc Cutting: A group of cutting processes wherein the severing of metals is effected by melting with the heat of an arc between an electrode and the base metal. See Carbon-Arc Cutting and Metal-Arc Cutting. See also Oxy-Arc Cutting.

Arc Oxygen Cutting: See Oxy-Arc Cutting.

Arc Voltage: The voltage across the welding arc.

Arc Welding: A group of welding processes wherein coalescence is produced by heating with an electric arc or arcs, with or without the application of pressure and with or without the use of filler metal.

Arm: See Horn.

As-Welded: The condition of weld metal, welded joints and weldments after welding prior to any subsequent thermal or mechanical treatment.

Atomic Hydrogen Welding: An arc-welding process wherein coalescence is produced by heating with an electric arc maintained between two metal electrodes in an atmosphere of hydrogen. Shielding is obtained from the hydrogen. Pressure may or may not be used and filler metal may or may not be used.

Automatic Gas Cutting: See Automatic Oxygen Cutting.

Automatic Oxygen Cutting: Oxygen cutting with equipment which performs the cutting operation without constant observation and adjustment of the controls by an operator. The equipment may or may not perform loading and unloading of the work. See Machine Oxygen Cutting.

Automatic Welding: Welding with equipment which performs the entire welding operation without constant observation and adjustment of the controls by an operator. The equipment may or may not perform the loading and unloading of the work. See Machine Welding.

Axis of a Weld: A line through the length of a weld, perpendicular to the cross-section at its center of gravity. See Figs. 1 and 2.

* The Master Chart and Process Charts, which classify the welding processes and show their differences and similarities, will be helpful in understanding some of these definitions. They are too large for inclusion in this standard and are available separately.

† Prepared by the AWS Committee on Definitions and Chart.

B

Back Bead: See Back Weld.

Backfire: The momentary recession of the flame into the torch tip followed by immediate reappearance or complete extinguishment of the flame.

Backhand Welding: A gas-welding technique wherein the flame is directed opposite to the progress of welding. See Fig. 4.

Backing: Material (metal, weld metal, asbestos, carbon, granular flux, etc.) backing up the joint during welding to facilitate obtaining a sound weld at the root.

Backing Bead: See Backing Weld.

Backing Pass: A pass made to deposit a backing weld.

Backing Ring: Backing in the form of a ring generally used in the welding of piping.

Backing Strap: See Backing Strip.

Backing Strip: Backing in the form of a strip.

Backing Weld: Backing in the form of a weld. See Fig. 6.

Back Pass: A pass made to deposit a back weld.

Back Weld: A weld deposited at the back of a single-groove weld. See Fig. 7.

Backstep Sequence: A longitudinal sequence wherein the weld bead increments are deposited in the direction opposite to the progress of welding the joint. See Block Sequence, Longitudinal Sequence, etc. See Fig. 8.

Backup: In flash and upset welding, a locator, used to transmit all or a portion of the upsetting force to the work pieces.

Bare Electrode: A filler-metal electrode, used in arc welding, consisting of a metal wire with no coating other than that incidental to the drawing of the wire.

Bare Metal-Arc Welding: An arc-welding process wherein coalescence is produced by heating with an electric arc between a bare or lightly-coated metal electrode and the work and no shielding is used. Pressure is not used and filler metal is obtained from the electrode.

Base Metal: The metal to be welded or cut.

Base-Metal Test Specimen: A test specimen composed wholly of base metal.

Beading: See String Beading and Weave Beading.

Bead Weld: A type of weld composed of one or more string or weave beads deposited on an unbroken surface. See Fig. 13.

Bevel: A type of edge preparation.

Bevel Angle: The angle formed between the prepared edge of a member and a plane perpendicular to the surface of the member. See Fig. 18.

Beveling: A type of chamfering.

Blacksmith Welding: See Forge Welding.

Block Brazing: A brazing process wherein coalescence is produced by the heat obtained from heated blocks applied to the parts to be joined and by using a nonferrous filler metal having a melting point above 800° F. but below that of the base metals. The filler metal is distributed in the joint by capillary attraction.

Block Sequence: A combined longitudinal and build-up sequence for a continuous multiple-pass weld wherein separated lengths are com-

pletely or partially built up in cross-section before intervening lengths are deposited. See Backstep Sequence, Longitudinal Sequence, etc. See Fig. 9.

Blowhole: See Gas Pocket.

Blowpipe: See Welding Torch or Cutting Torch.

Bond: The junction of the weld metal and the base metal, or the junction of the base metal parts when weld metal is not present. See Fig. 21.

Bottle: See Cylinder.

Boxing: The operation of continuing a fillet weld around a corner of a member as an extension of the principal weld. See Fig. 22.

Braze: A weld wherein coalescence is produced by heating to suitable temperatures above 800° F. and by using a nonferrous filler metal, having a melting point below that of the base metals. The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction.

Braze Welding: A method of welding whereby a groove, fillet, plug or slot weld is made using a nonferrous filler metal, having a melting point below that of the base metals but above 800° F. The filler metal is not distributed in the joint by capillary attraction. (Bronze Welding, formerly used, is a misnomer for this term.)

Brazed Joint: A union of two or more members produced by the application of a brazing process.

Brazing (Noun): A group of welding processes wherein coalescence is produced by heating to suitable temperatures above 800° F. and by using a nonferrous filler metal, having a melting point below that of the base metals. The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction.

Brazing Technique: See Welding Technique.

Build-Up Sequence: The order in which the weld beads of a multiple-pass weld are deposited with respect to the cross-section of the joint. Block-Sequence, Longitudinal Sequence, etc. See Fig. 10.

Burner: See Oxygen Cutter.

Burning In: See Flow Welding.

Butt Joint: A joint between two members lying approximately in the same plane. See Fig. 17.

Butt Weld: A weld in a butt joint.

Button: In the destructive testing of spot-, seam- and projection-welded specimens, that part of a weld, including all or part of the nugget, which tears out.

C

Capillary Attraction: The phenomenon by which adhesion between the molten filler metal and the base metals, together with surface tension of the molten filler metal, distribute the filler metal between the properly fitted surfaces of the joint to be brazed.

Carbon-Arc Cutting: An arc-cutting process wherein the severing of metals is effected by melting with the heat of an arc between a carbon electrode and the base metal.

Carbon-Arc Welding: An arc-welding process wherein coalescence is produced by heating with an electric arc between a carbon electrode and

the work and no shielding is used. Pressure may or may not be used and filler metal may or may not be used.

Carbon Electrode: A non-filler-metal electrode, used in arc welding, consisting of a carbon or graphite rod.

Carbon-Electrode Arc Welding: A group of arc-welding processes wherein carbon electrodes are used. See Shielded Carbon-Arc Welding, Inert-Gas Carbon-Arc Welding, Carbon-Arc Welding and Twin-Carbon Arc Welding.

Carbonizing Flame: See Reducing Flame.

Carburizing Flame: See Reducing Flame.

Cascade Sequence: A combined longitudinal and build-up sequence wherein weld beads are deposited in overlapping layers. (In manual shielded metal-electrode arc-welding a backstep sequence is normally used.) See Block Sequence, Build-Up Sequence, Longitudinal Sequence, etc. See Fig. 11.

Chain Intermittent Fillet Welding: Two lines of intermittent fillet welding on a joint wherein the fillet weld increments in one line are approximately opposite to those in the other line. See Fig. 23.

Chamfer: See Edge Preparation.

Chamfering: The preparation of a contour, other than for a square groove weld, on the edge of a member for welding.

Chill Ring: See Backing Ring.

Circular Seam Welding: See Transverse Seam Welding.

Circumferential Seam Welding: See Transverse Seam Welding.

Coated Electrode: See Covered Electrode and Lightly-Coated Electrode.

Collar: The reinforcing metal of a non-pressure thermit weld.

Commutator-Controlled Welding: The making of a number of spot or projection welds wherein several electrodes, in simultaneous contact with the work, progressively function under the control of an electrical commutating device.

Complete Fusion: Fusion which has occurred over the entire base-metal surfaces exposed for welding. See Fig. 26.

Complete Joint Penetration: Joint penetration which extends completely through the joint. See Joint Penetration. See Fig. 29.

Complete Penetration: See Complete Joint Penetration.

Composite Electrode: A filler-metal electrode, used in arc welding, consisting of more than one metal component combined mechanically. It may or may not include materials which protect the molten metal from the atmosphere, improve the properties of the weld metal or stabilize the arc.

Composite Joint: A joint wherein welding is used in conjunction with a mechanical joining process.

Concave Fillet Weld: A fillet weld having a concave face. See Fig. 31.

Concavity: The maximum distance from the face of a concave fillet weld perpendicular to a line joining the toes. See Fig. 31.

Concurrent Heating: The application of supplemental heat to a structure during a welding or cutting operation.

Cone: The conical part of a gas flame next to the orifice of the tip. See Figs. 38, 39 and 40.

Continuous Sequence: A longitudinal sequence wherein each pass is

made continuously from one end of the joint to the other. See Back-step Sequence, Longitudinal Sequence, etc.

Continuous Weld: A weld which extends without interruption for its entire length.

Convex Fillet Weld: A fillet weld having a convex face. See Fig. 32.

Convexity: The maximum distance from the face of a convex fillet weld perpendicular to a line joining the toes. See Fig. 32.

Cool Time: In multiple-impulse welding and seam welding, the time interval between successive heat times. See Figs. 53, 54 and 55.

Corner Joint: A joint between two members located approximately at right angles to each other in the form of an *L*. See Fig. 17.

Corona: The area sometimes surrounding the nugget of a spot weld at the faying surfaces, which provides a degree of bonding.

Cover Glass: A clear glass used in goggles, hand shields and helmets to protect the filter glass from spattering material.

Covered Electrode: A filler-metal electrode, used in arc welding, consisting of a metal core wire with a relatively thick covering which provides protection for the molten metal from the atmosphere, improves the properties of the weld metal and stabilizes the arc.

Crater: A depression at the termination of a weld bead.

Crater Crack: A crack in the crater of a weld bead.

Cross Wire Weld: A projection weld made between crossed wires or bars.

Current Regulator: An automatic electrical control device for maintaining a constant current in the primary of the welding transformer.

Cutting Attachment: A device which is attached to a gas-welding torch to convert it into an oxygen-cutting torch.

Cutting Nozzle: See Cutting Tip.

Cutting Tip: That part of an oxygen-cutting torch from which the gases issue.

Cutting Torch: A device used in oxygen cutting for controlling and directing the gases used for preheating and the oxygen used for cutting the metal.

Cylinder: A portable cylindrical container used for transportation and storage of a compressed gas.

Cylinder Manifold: See Manifold.

D

Deposit Sequence: See Deposition Sequence.

Deposited Metal: Filler metal that has been added during a welding operation.

Deposition Efficiency: The ratio of the weight of deposited metal to the net weight of electrodes consumed, exclusive of stubs.

Deposition Rate: The weight of metal deposited in a unit of time.

Deposition Sequence: The order in which the increments of weld metal are deposited. See Longitudinal Sequence and Build-Up Sequence.

Depth of Fusion: The distance that fusion extends into the base metal from the surface melted during welding. See Fig. 25.

Die:

Resistance Welding.—A member usually shaped to the work contour to clamp the parts being welded and conduct the welding current.

Forge Welding.—A device used in forge welding primarily to form the work while hot and apply the necessary pressure.

Die Welding: A forge-welding process wherein coalescence is produced by heating in a furnace and by applying pressure by means of dies.

Dip Brazing: A brazing process wherein coalescence is produced by heating in a molten chemical or metal bath and by using a nonferrous filler metal, having a melting point above 800° F. but below that of the base metals. The filler metal is distributed in the joint by capillary attraction. When a metal bath is used, the bath provides the filler metal.

Double-Bevel Groove Weld: A type of groove weld. See Fig. 12.

Double-J Groove Weld: A type of groove weld. See Fig. 12.

Double-U Groove Weld: A type of groove weld. See Fig. 12.

Double-Vee Groove Weld: A type of groove weld. See Fig. 12.

Downhand: See Flat Position.

Drag: The distance between the point of exit of the cutting oxygen stream and the projection, on the exit surface, of the point of entrance. See Fig. 33.

Dynamic Electrode Force: See Electrode Force.

E

Edge Joint: A joint between the edges of two or more parallel or nearly parallel members. See Fig. 17.

Edge Preparation: The contour prepared on the edge of a member for welding.

Effective Length of Weld: The length of weld throughout which the correctly proportioned cross-section exists.

Electrode:

Arc Welding.—See Bare Electrode, Carbon Electrode, Composite Electrode, Covered Electrode, Lightly-Coated Electrode, Metal Electrode and Tungsten Electrode.

Resistance Welding.—The part or parts of a resistance-welding machine through which the welding current and, in most cases, pressure are applied directly to the work. The electrode may be in the form of a rotating wheel, rotating roll, bar, cylinder, plate, clamp, chuck or modification thereof.

Electrode Force:

Dynamic.—In spot, seam and projection welding, the force (pounds) between the electrodes during the actual welding cycle.

Theoretical.—In spot, seam and projection welding, the force, neglecting friction and inertia, available at the electrodes of a resistance welding machine by virtue of the initial force application and the theoretical mechanical advantage of the system.

Static.—In spot, seam and projection welding, the force between the electrodes under welding conditions, but with no current flowing and no movement in the welding machine.

Electrode Holder: A device used for mechanically holding the electrode and conducting current to it.

Electrode Lead: The electrical conductor between the source of arc-welding current and the electrode holder. See Figs. 34 and 35.

Electrode Skid: During spot, seam or projection welding, the sliding of an electrode along the surface of the work.

Electronic Heat Control: A device for adjusting the heating value (rms value) of the current in making a resistance weld by controlling the ignition or firing of the tubes in an electronic contactor. The flow of current is initiated each half-cycle at an adjustable time with respect to the zero point on the voltage wave.

End Return: See Boxing.

F

Face of Weld: The exposed surface of a weld, made by an arc- or gas-welding process, on the side from which welding was done. See Fig. 20.

Face Shield: See Hand Shield.

Faying Surface: That surface of a member which is in contact with another member to which it is to be joined.

Filler Metal: Metal to be added in making a weld.

Fillet Weld: A weld of approximately triangular cross-section joining two surfaces approximately at right angles to each other in a lap joint, tee joint or corner joint. See Figs. 31 and 32.

Fillet Weld Size: See Size of Weld.

Filter Glass: A glass, usually colored, used in goggles, helmets and hand shields to exclude harmful light rays.

Flame Cutting: See Oxygen Cutting.

Flame Gouging: See Oxygen Gouging.

Flash: The molten metal which is expelled, or which is squeezed out by the application of pressure, and solidifies around the weld.

Flashback: A recession of the flame into or back of the mixing chamber of the torch.

Flash-Butt Welding: See Flash Welding.

Flashing Time: In flash welding the time during which the flashing action is taking place. See Fig. 56.

Flash-Off Time: See Flashing Time.

Flash Weld: A weld made by flash welding. See Fig. 16.

Flash Welding: A resistance-welding process wherein coalescence is produced, simultaneously over the entire area of abutting surfaces, by the heat obtained from resistance to the flow of electric current between the two surfaces, and by the application of pressure after heating is substantially completed. Flashing and upsetting are accompanied by expulsion of metal from the joint.

Flat Position: The position of welding wherein welding is performed from the upper side of the joint and the face of the weld is approximately horizontal. See Figs. 1 and 2.

Flow Brazing: A brazing process wherein coalescence is produced by heating with molten nonferrous filler metal poured over the joint until brazing temperature is attained. The filler metal has a melting point above 800° F. but below that of the base metals and is distributed in the joint by capillary attraction.

Flow Welding: A welding process wherein coalescence is produced by heating with molten filler metal, poured over the surfaces to be welded until the welding temperature is attained and until the required filler

metal has been added. The filler metal is not distributed in the joint by capillary attraction. (Burning In, formerly used, is a misnomer for this term.)

Flux: Fusible material used in welding or oxygen-cutting to dissolve and facilitate removal of oxides and other undesirable substances.

Flux-Oxygen Cutting: An oxygen-cutting process wherein severing of metals is effected by using a flux to facilitate the cutting.

Forehand Welding: A gas-welding technique wherein the flame is directed toward the progress of welding. See Fig. 5.

Forge-Delay Time: In spot and projection welding, the time between the beginning of weld time, or weld interval, and the time when the electrode force first reaches the specified pressure for forging. See Fig. 54.

Forge Welding: A group of welding processes wherein coalescence is produced by heating in a forge or other furnace and by applying pressure or blows.

Full Fillet Weld: A fillet weld whose size is equal to the thickness of the thinner member joined.

Furnace Brazing: A brazing process wherein coalescence is produced by the heat obtained from a furnace and by using a nonferrous filler metal, having a melting point above 800° F. but below that of the base metals. The filler metal is distributed in the joint by capillary attraction.

Fused Zone: See Fusion Zone, Nugget and Bond.

Fusion: The melting together of filler metal and base metal, or of base metal only, which results in coalescence. See Depth of Fusion.

Fusion Zone: The area of base metal melted as determined on the cross-section of a weld. See Fig. 21.

G

Gas Brazing: See Torch Brazing.

Gas Cutter: See Oxygen Cutter.

Gas Cutting: See Oxygen Cutting.

Gas Gouging: See Oxygen Gouging.

Gas Pocket: A weld cavity caused by entrapped gas.

Gas Regulator: See Regulator.

Gas Torch: See Welding Torch and Cutting Torch.

Gas Welding: A group of welding processes wherein coalescence is produced by heating with a gas flame or flames, with or without the application of pressure, and with or without the use of filler metal.

Goggles: See Welding Goggles.

Groove: The opening provided for a groove weld.

Groove Angle: The total included angle of the groove between parts to be joined by a groove weld. See Fig. 18.

Groove Face: That surface of a member included in the groove. See Fig. 19.

Groove Radius: The radius of a J- or U-Groove. See Fig. 18.

Groove Weld: A weld made in the groove between two members to be joined. The standard types of groove welds (Fig. 12) are as follows.

Square Groove Weld
Single-Vee Groove Weld
Single-Bevel Groove Weld

Single-U Groove Weld
Single-J Groove Weld
Double-Vee Groove Weld
Double-Bevel Groove Weld
Double-U Groove Weld
Double-J Groove Weld

Ground Connection: The connection of the work lead to the work. See Figs. 34 and 35

Ground Lead: See Work Lead.

H

Hammer Welding: A forge-welding process wherein coalescence is produced by heating in a forge or other furnace and by applying pressure by means of hammer blows.

Hand Shield: A protective device, used in arc welding, for shielding the face and neck. A hand shield is equipped with a suitable filter glass and is designed to be held by hand.

Hard Surfacing: See Surfacing.

Heat-Affected Zone: That portion of the base metal which has not been melted, but whose mechanical properties or microstructures have been altered by the heat of welding or cutting. See Fig. 41.

Heat Time: In multiple impulse welding or seam welding, the time that the current flows during any one impulse. See Figs. 53, 54 and 55.

Heating Gate: The opening in a thermit mold through which the parts to be welded are preheated.

Helmet: A protective device, used in arc welding, for shielding the face and neck. A helmet is equipped with a suitable filter glass and is designed to be worn on the head.

Hold Time:

1. In spot and projection welding, the time during which force is applied at the point of welding after the last impulse of current ceases to flow. See Figs. 53 and 54.
2. In seam, flash and upset welding the time during which force is applied to the work after current ceases to flow. See Figs. 55, 56 and 57.

Horizontal Fixed Position:

Pipe Welding.—The position of a pipe joint wherein the axis of the pipe is approximately horizontal and the pipe is not rotated during welding. See Fig. 3.

Horizontal Position:

Fillet Weld.—The position of welding wherein welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface. See Fig. 2.

Groove Weld.—The position of welding wherein the axis of the weld lies in an approximately horizontal plane and the face of the weld lies in an approximately vertical plane. See Fig. 1.

Horizontal Rolled Position:

Pipe Welding.—The position of a pipe joint wherein welding is performed in the flat position by rotating the pipe. See Fig. 3.

Horn: In resistance welding, a beam or arm, extending from the frame