NEW LESSONS IN ARC WELDING

THE LINCOLN ELECTRIC COMPANY

NEW LESSONS IN ARC WELDING

Price $1.00 postpaid in U.S.A.
$1.50 elsewhere

This book has been published as a service to the welding industry for educational purposes.

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NEW LESSONS IN ARC WELDING is a new book resulting from an enlargement, by the addition of new material, of a series of lessons which forms the basis of instruction in The Lincoln Arc Welding School.

In the Lincoln School two types of courses are given —the basic course in the fundamentals of arc welding, and the advanced courses in alloy welding, sheet metal welding and pipe welding. The basic course is devoted entirely to the welding of mild steel in all positions and is thus concerned with Lessons 1 to 32 inclusive. The other lessons form the basis for the advanced courses.

The Welding Application Supplement is not made up of lessons but contains new procedure data for obtaining lowest cost welding, supplementary information to help operators better understand the welding process and suggestions for easy ways to use welding in place of casting in fabricating machinery.

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FOREWORD

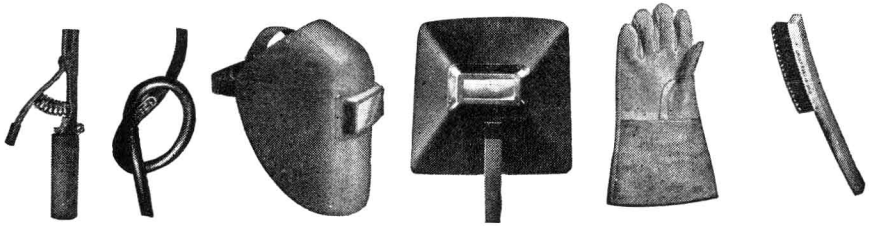
THE objective of these lessons is to present in a concise manner certain fundamental facts of welding, the knowledge of which will enable the welder to use the welding process successfully and economically. The Welding School of The Lincoln Electric Company adds to this book the personal supervision of highly trained instructors who direct the activities of the student with the end in mind that he may become adequately trained for welding.

Welding, as ordinarily considered, may be defined as a method of joining metals by fusing the edges or surfaces, causing them to become molten, and thereby be fused together without pressure being applied. This is known as fusion welding.

In welding, use is made of an electrode held in a holder which is connected to one terminal of the generator, the base metal or metal being welded is connected to the other. The terminal of the generator to which the electrode is connected depends upon the kind of electrode used and determines what is known as polarity for D. C. machines.

The electrode is touched to the base metal, withdrawn, and held so as to form and maintain an arc. A small pool or crater is melted in the base metal. The electrode is also melted and deposited in the crater. The metal in the crater is agitated mixing the molten electrode with the base metal forming a dense joint. When the electrode is metal, the process is called the metallic arc process; when carbon, the carbon arc process.

Obviously, the metallic electrode furnishes additional metal to the base metal. But in the case of the carbon arc a filler rod may be used—the rod being fed



Electrode Holders *Welding Cable* *Head Shields* *Face Shields* *Protective Clothing* *Cleaning Brushes*

into the arc and melted, fused, and mixed as outlined above for the metallic arc.

The details of these operations are given in the lessons.

Welding current is obtained from special generators or transformers, the details of which are given in the lessons.

It is evident that the arc is very hot (temperature of approx. 10,000°F.) and therefore throws off both light and heat. It is necessary that proper protection be used. For eye protection a special glass in either a head or hand shield is used. *It is essential that this glass be used at all times when looking AT THE ARC.* The special glass being expensive is protected by an ordinary clear glass.

Gloves, preferably of gauntlet type, should be worn to protect the hands. A suitable leather apron is of great use in protecting the clothing, particularly when operator is sitting at his work.

It is also important that trousers without cuffs are worn and that legs of the trousers be held down over the shoe tops. Bicycle clips are excellent for this purpose. Otherwise there is a possibility of hot metal falling into the cuffs or shoes.

Where other work is done in the same shop, booths are necessary to protect the men from the arc rays. The booth and walls of the shop which might reflect rays should be a dull black. Fireproofed canvas curtains on a pipe frame make a very acceptable booth. Wood or sheet metal are also used.

Inside the booth should be a welding table. A metal top, properly supported at a correct height, with provisions for good connection of ground cable, is about all that is required. The operator can construct this of structural parts. An insulated hook, or something similar, should be provided for the electrode holder.

The next item is the electrode holder. This should be mechanically strong, light in weight, and be capable of holding the electrode firmly in position during welding, but allowing easy removal and replacement of electrode. It must not become too hot. The connection from electrode holder to machine is made of cable, which should be very flexible so as to offer a minimum of restraint to the operator's motions.

In addition to the equipment outlined above, the following should be available: Steel scratch brush for cleaning welds, removing rust, etc.: tools for removing scale and slag from welds; carbon and copper blocks for backing up strips; and the usual shop equipment, such as vises, hammers, tongs, etc.

The arrangement of table and work should be such that operator may be comfortable. A strained, awkward position interferes with the doing of good work, whereas an easy, comfortable position is helpful and results in better production at lower costs.

The Lincoln Electric Company is interested in the welder and is doing everything possible to help him increase his knowledge of and skill in welding and invites correspondence with welders in regard to any problem they may have.

Questions for this section are on Page 129; Answers on Page 147.

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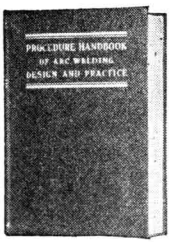
AIDS FOR ARC WELDING PROGRESS

In the interests of scientific and social advancement through the use of arc welding the Publishers of this book also have other books and bulletins on the various phases of arc welding application for sale. The following books are recommended for engineers, designers, production supervisors, shop men, welders, students and others seeking advancement through knowledge of arc welding.



"Procedure Handbook of Arc Welding Design and Practice"

The New Handbook contains up-to-date facts about all aspects of the arc welding process and its many profitable applications, compiled and edited for quick reference and easy understanding.

1200 pages of up-to-date facts.

In nine parts—(1) Welding Processes and Equipment . . . (2) Weldability . . . (3) Techniques, Procedures, Speeds and Costs . . . (4) Basic Design Data for Welded Construction . . . (5) Machine Design with Arc Welded Construction . . . (6) Designing of Arc Welded Structures . . . (7) Inspection and Testing . . . (8) Applications . . . (9) Reference Data.

Written clearly. Profusely illustrated by 1338 photos and drawings. Well indexed for quick, detailed reference.

Recognized throughout the world as the authentic reference guide on Arc Welding. Approximately 300,000 copies of previous editions have been sold.

Size 6" x 9" x 1⅝"—ideal for use in office, shop or school. Printed on fine paper. Bound in semi-flexible simulated leather, gold embossed.

Price only $2.00 postpaid in U.S.A.; $2.50 elsewhere. Make checks or money orders out to The Lincoln Electric Company.

"Simple Blueprint Reading"

Compiled and published primarily for welders and others concerned with mechanical construction. Guides the student in easy stages to a complete mastery of blueprint reading. By enabling shop men to interpret drawings correctly and to answer blueprint questions for themselves, this book provides a valuable aid for advancement. A comprehensive explanation with practical examples of drawings illustrating a wide variety of manufacture and construction. Contains 144 pages 6" x 9". Printed on fine paper. Bound in simulated leather, gold embossed. Price 50c, postpaid anywhere in U.S.A.; 75c elsewhere. Make checks or money orders out to The Lincoln Electric Company.

"Welding Metallurgy"

A complete discussion of all phases of the subject. Authoritative. 500 pages. About 203 illustrations. Bound in durable cover of simulated leather. Price $2.50 postpaid in the U.S.A.; $3.00 elsewhere. Make checks or money orders payable to The Lincoln Electric Company.

"The Stabilizer"

"The Stabilizer", published by Lincoln, is virtually the official organ of the vast army of men who weld. Each issue is packed full of practical welding ideas contributed by welders themselves, promoting good welding and the advancement of the industry. Free to employed welders and supervisors. Give position, name and address of company and home address.

"Lincoln's Incentive System"

Lincoln's Incentive System is written by Mr. J. F. Lincoln, president of the Lincoln Electric Company. He explains how to organize a business for making "more and more of a better and better product at a lower and lower selling price."

Mr. Lincoln reveals the philosophy and ideas responsible for the unique business success of the Lincoln Electric Company. He tells how incentive management can produce high wages, high employment, high production and *low selling prices*; how it can be used in any type of business whether large or small.

A 192 page book, cloth bound, published by the McGraw Hill Company. Price $2.00. Make checks or money orders payable to the Lincoln Electric Company.

MOVIES

Movies in color and sound are available to schools, firms and organizations. These include: "Magic Wand of Industry", a general story of what arc welding is and its many uses; "Prevention and Control of Distortion in Arc Welding"; "Design of Arc Welded Structures"; "Designing Machinery for Arc Welding" and "Welding Comes to the Farm." Film size, 16mm. No charge except for transportation. Write Lincoln for further information.

* * * * *

THE JAMES F. LINCOLN ARC WELDING FOUNDATION

The James F. Lincoln Arc Welding Foundation was established in 1936 by the Lincoln Electric Company for the scientific and/or practical development of the arc welding process. As a contribution to scientific progress and to promote industrial progress through education the Foundation has produced and published the following books. Copies should be ordered from the James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio.

"Design for Welding"

This book presents a significant record of the progress of arc welding. It contains 82 outstanding and representative papers from the Lincoln Arc Welding Foundation's $200,000 "Design for Progress" Award Program. Over 1,000 pages describe welded designs of machines and structures of all kinds and sizes. Well illustrated with hundreds of photographs, drawings, calculations, cost data and tables. Gives you the benefit of the experience of outstanding men with welded design.

This volume is a convenient 6″ x 9″ desk size, well arranged for easy reference; printed on durable stock, bound in semi-flexible, simulated leather, gold embossed; price $2.00 in U.S.A., $2.50 elsewhere. Published and sold by The James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio.

"Studies in Arc Welding"

A volume of 98 outstanding studies of the James F. Lincoln Arc Welding Foundation. Information on a wide variety of arc welding applications representing every type of industry. 1281 pages, 1007 illustrations. Size 6″ x 9″. Bound in semi-flexible leather, gold embossed. Price $1.50, postpaid in U.S.A.; $2.00 elsewhere. Make checks or money orders payable to the James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio.

"Maintenance Arc Welding"

Another important book developed by the James F. Lincoln Arc Welding Foundation. Comprises 25 significant papers in the maintenance classification. Deals with the use of arc welding in reclaiming broken and worn parts and gives details in the application of welding to the fabrication of replacement parts. 233 pages. 242 illustrations. Size 6" x 9". Bound in simulated leather. Price: 50c postpaid in U.S.A.; 75c elsewhere.

"Introduction to Mechanical Design"

A complete textbook, 621 pages, for studying machine design. Published and sold by Ronald Press, 15 East 26th Street, N. Y. 10, N. Y. Price $6.50, plus postage. Order from Ronald Press.

"Weld Design"

A concise volume on the welded design of machine bases. Recommended for publication by the Jury of Award of the Lincoln Foundation's Textbook Award Program. Covers: materials, design data and designing principles, welding specifications, welding procedure, welding processes, flame cutting and flame hardening, forming of metals, estimating costs. 216 pages, 135 illustrations, printed on heavy paper and bound in heavy cloth covers. Published and sold by Prentice-Hall, Inc., 70 Fifth Ave., New York 11, New York. Orders and inquiries should be sent to Prentice-Hall, Inc. Price $6.65, plus postage.

"Welded Deck Highway Bridges"

This book contains details of designs submitted in the 1949 "Welded Bridges of the Future" Award Program of the Lincoln Foundation. Significant details of the designs are presented rather than complete designs. Covers: structural types, floor systems, new sections, special connections and details, quantities and costs. 247 pages, over 100 drawings, clearly reproduced on excellent paper, cloth covered. Price $2.00 in U.S.A., $2.50 elsewhere, postage prepaid. Order from The James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio.

"Plans for Making Farm Tools and Equipment"

A 32-page booklet of information and plans for making 25 labor-saving farm projects; detailed drawings, bill of materials and complete building data. Price 25c per copy from The James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio.

The project plans are: Welding positioner, welding table and stool, vise stand, milk can dolly, tool carrier, 4 types of trailers, two-wheeled cart, log saw, table saw, buzz saw, power cutter, 2 manure loaders, buck rake, 3 post hole diggers, grapple fork, hay loader, drill press, milk pail rack, and stile.

"Arc Welding Lessons for School and Farm Shop"

A book for teaching and learning the skills used with farm arc welding equipment. Contains both informational and operational lessons. Explains how to weld, solder, braze, heat, cut, temper, hard surface with arc welding equipment. Clear step-by-step outline for each lesson given with a typical job explained for practicing the lesson. 342 pages, 550 illustrations, illustrated glossary, 26 pages of welded projects; bound in semi-flexible simulated leather, gold embossed. Price $1.00 in U.S.A., $1.50 elsewhere. Order from The James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio.

"Welding Helps for Farmers"

A handy manual for farm owners. The book has 448 pages and 310 illustrations of ideas on repairing and building farm equipment. Bound in durable cover of simulated leather. Price $1.00 postpaid in U.S.A.; elsewhere $1.50.

Make checks or money orders payable to the James F. Lincoln Arc Welding Foundation, P.O. Box 5728, Cleveland 1, Ohio.

"Structural Design in Metals"

A complete textbook, 591 pages, for studying structural design. Published and sold by Ronald Press, 15 East 26th Street, N. Y. 10, N. Y. Price $6,50, plus postage. Order from Ronald Press.

INDEX TO LESSONS

INDEX TO LESSONS

LESSONS IN ARC WELDING

Instructions to the Operator

Do not play with the welding machine. Make a definite plan and follow it through. Learn the fundamental principles and wherever possible reduce your problems to those fundamental principles. You will find the solution of your problem very much easier if you do.

Practice making samples and continue practicing and then do more practicing.

Open up the welds, examine them, criticize your work, ask criticism from others. Because you are melting a lot of metal is no sign that you are welding.

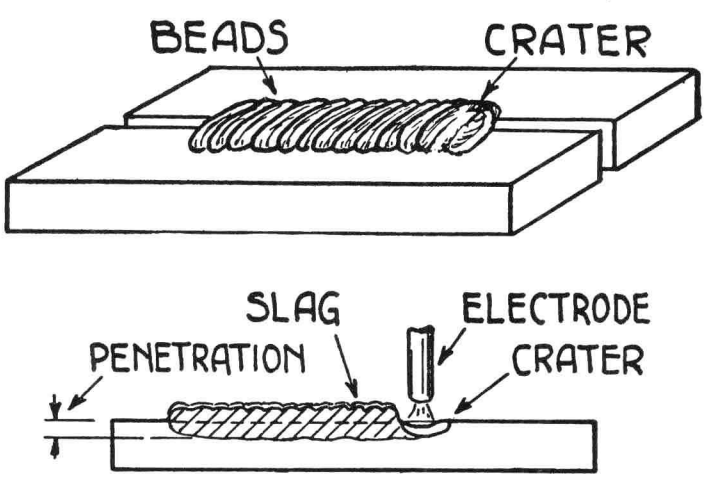


Fig. 1

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Caution—Never look at the arc without using a protective glass to shield the eyes. Use a good high-grade welding lens in all cases.

Direct exposure or a "flash", will result in a very painful, but not permanent, burning of the eyes. If the eyes are exposed to the rays of the arc an application of cool boric acid is helpful, or a few drops of 5% argyrol every 4 or 5 hours. Aspirin will relieve pain and headache and permit rest, which is very helpful in promoting quick recovery.

The position assumed at work has a great bearing on the kind of work done and the speed at which it is done. Therefore, be as comfortable as the job allows. It's easier on the operator and results in better work at lower cost.

The electrode is the wire or rod held in the holder. The electrode is melted, as is also the base metal, and the whole fused together without pressure. This is fusion welding.

It may be well at this point to explain, define and illustrate certain terms customarily used by welders.

The bead is the metal deposited by the electrode. See Fig. 1.

When the arc strikes the parent metal, metal is melted forming a pool or pocket. This is the crater. Its depth indicates the approximate amount of penetration.

A correct bead should have good penetration, no overlap or undercutting. Overlap is the amount of deposited metal "overlapping" but not fusing or melting into the parent metal. Undercutting is a melting of base metal along the edge of the weld which results in a depression. See Fig. 2 for explanation of these terms.

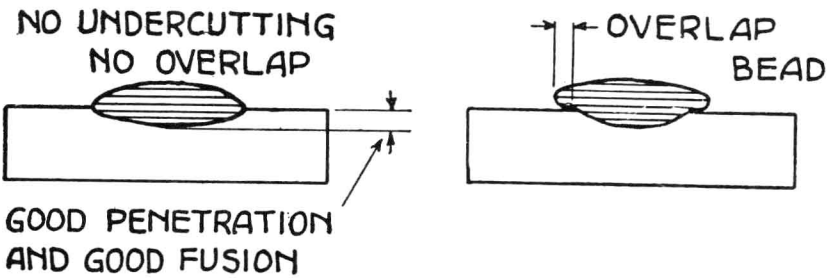

Fig. 2

Questions for this lesson are on Page 129; Answers on Page 147.

LESSON 1-A

Object—The study of the "Shield-Arc" S.A.E. Arc Welder with Dual Continuous Control.
Apparatus—Lincoln "Shield-Arc" S.A.E. Welder.
Material—Scrap steel, carbon holder, 1/4 or 3/8" carbons.

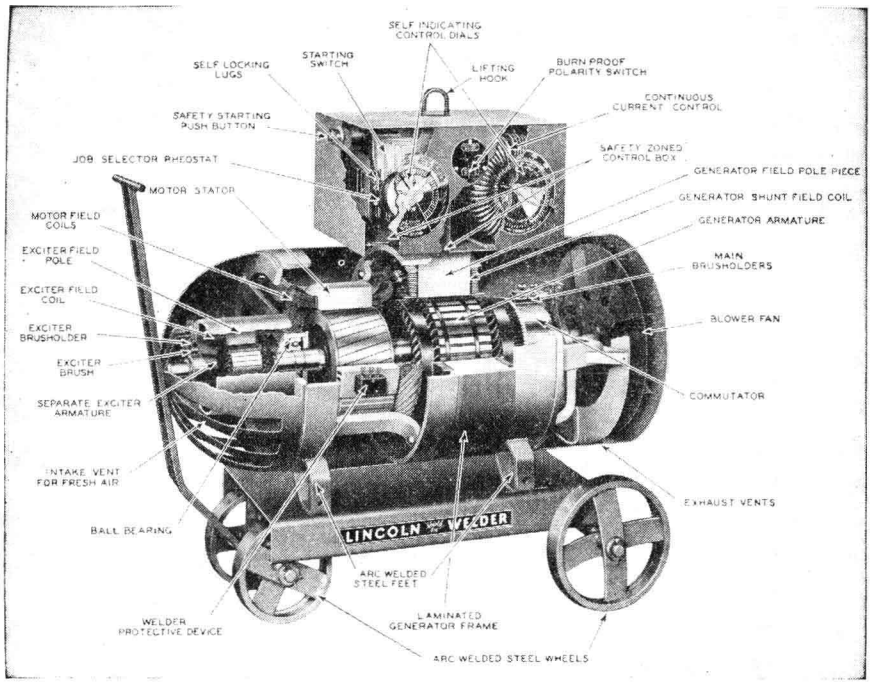

Fig. 1 Cut-away view of "Shield-Arc" S.A.E. Welder

Dual Continuous Control of the "Shield-Arc" S.A.E. Welder gives the operator complete freedom in choice of arc characteristics and current. Self-Indicating dials of this control make the proper setting practically automatic. This enables the operator to set the machine for the proper volt-ampere combination to do any kind, type or position of welding.

Setting the Self-Indicating dials is as simple as operating the radio in your living room. When you tune in a radio station, one dial gives you the station you want while the other varies the volume to suit your needs. In the same manner, welders can "tune in" the arcs to suit their various welding jobs. See Fig. 2. The left-hand dial, the "Job Selector," is for selecting the proper ***type*** **of arc. The other is the current adjustment dial which provides the** proper arc *intensity*.

To understand the principle of Dual Continuous Control, it must first be realized that there are two types of welding voltage. These are the *open circuit* voltage and the *arc* voltage. The open circuit voltage is the voltage generated by the welding machine when no welding is being done. The arc voltage is the voltage between the electrode and the work during welding.

Open circuit voltages are between 50 and 100; arc voltages are between

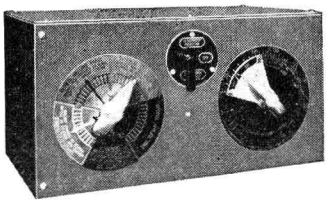

Fig. 2. Controls of "Shield-Arc" S.A.E. Welder

18 and 36. The open circuit voltage drops to the arc voltage when the arc is struck and the welding load comes on the machine. Value of the arc voltage is determined largely by the length of the arc and, to some degree, by the type of electrode being used. If the arc is *shortened,* the arc voltage *decreases.* If the arc is *lengthened,* the arc voltage *increases.* The value of open circuit voltage of the welding machine has little effect on the arc voltage—but it does determine the *arc characteristics.*

Experienced welders know that the arc characteristics required for flat welding are different from those needed for vertical and overhead welding. Two welding applications can require the same welding current, but because of the difference in metals or welding positions will require different arc characteristics. The most satisfactory welding machine is one which provides arc characteristics for all conditions and the three positions of welding—flat, vertical and overhead—and makes this complete range readily available with convenient controls. Those are the reasons behind development of Dual Continuous Control, with its Self-Indicating dials.

The "Job Selector" or voltage control is divided into three differently-colored segments, labeled "Large Electrodes", "Normal Welding", "Vertical and Overhead", and a fourth segment in black for special low current applications. The setting labeled "Large Electrodes" has the highest voltage, and the others are successively lower in the order named.

The Current Selector has colored arrows corresponding to the segments of the voltage control. In setting the machine, the operator should first choose the voltage control setting required by the work and desired results. Then by setting the arrow of corresponding color on the current control, the exact current suitable for the work is obtained.

What effect does Dual Continuous Control have on the performance of the welding arc? Consider what happens to the welding current when this control is operated.

By varying the left-hand control, the "Job Selector", the open-circuit voltage

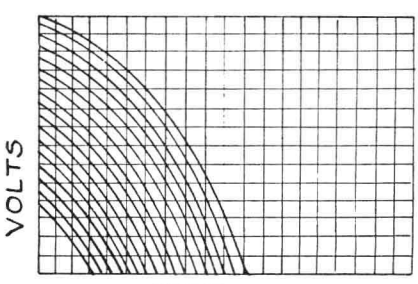

Fig. 3

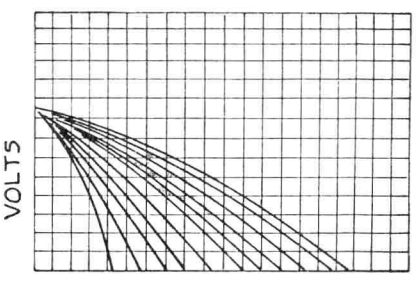

Fig. 4

is changed, producing any desired volt-ampere curve such as those shown in Fig. 3.

By varying the right-hand control, the "current control", the welding current is changed with any given open circuit voltage producing any desired volt-ampere curve such as those shown in Fig. 4. A great number of volt-ampere curves can be produced for each open-circuit voltage adjustment.

In other words, the combination of the two controls allows the operator to blanket the entire range of the welder as shown in Fig. 5 He can choose a volt-ampere setting which can be *anywhere* between the curve of lowest open-circuit voltage (Curve 1) and minimum current, and that of the highest open-circuit voltage and maximum current (Curve 2) (Fig. 5.)

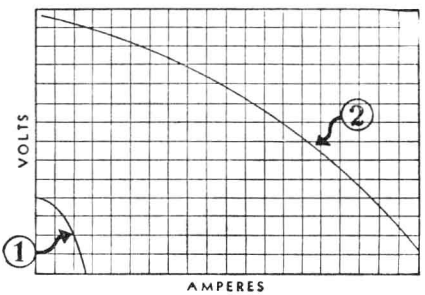

Fig. 5

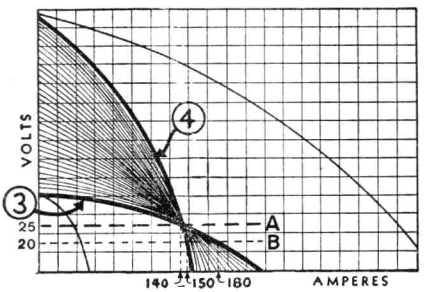

Fig. 6

For downhand welding in the flat position the increase and decrease of current moving in and out of the crater is not necessary or desirable. Then the "Job Selector" is set in the range marked "normal" which is a fairly high open circuit voltage setting. For this setting, there is little change in the current at the arc when the arc is lengthened or shortened.

Select any welding current and its corresponding arc voltage, such as point A in Fig. 6. This is a current of 140 amperes and 25 volts. Through that point, any number of volt-ampere curves can be produced, varying in slope as shown, from the gradually sloping Curve 3, to the steep Curve 4.

For example, when set for Curve 4, a shortening of the arc, so that the voltage drops to B, or 20 volts, causes little change in the welding current; the current increases only to 150 amperes. Hence, this type of setting is more suitable for applications such as down hand flat welding with large sized electrodes.

When welding in the vertical or overhead positions, the operator generally moves his electrode up and down, or back and forth, in and out of the molten puddle. As the electrode is moved out of the puddle, the operator would like it to cease depositing, so the puddle will freeze and no metal will be deposited on the plates outside the crater. Since this is not completely possible, he is satisfied for its deposition to slow down while it is out of the crater.

When the operator brings the electrode back into the molten puddle, he immediately wants more metal deposited. He would also like an increase in current to obtain more "arc force," so that the stream of electrode metal will penetrate deep into the parent plate. Then the cycle is repeated as he

withdraws the electrode from the crater. The needs of the operator are made possible with Dual Continuous Control.

If he desires to weld overhead, setting the "Job Selector" or voltage control in the range marked "Overhead and Vertical," the machine will respond exactly as the operator wishes. Setting the "Job Selector" in this range gives low open circuit voltage setting. With this setting, the current decreases rapidly and less metal is burned off the electrode when the arc is lengthened and the electrode is moved out of the puddle. The current will increase rapidly as the arc is shortened and the electrode is moved back into the puddle.

Now to see technically why the operator, when welding vertical or overhead, can get this arc characteristic at any welding current with Dual Continuous Control, glance at Fig. 6.

Suppose the arc were shortened, decreasing the arc voltage to B, or 20 volts. It is clearly evident that this shortening of the arc gives a material increase in the welding amperes when set for Curve 3. It makes the current 180 amperes. Hence, this setting gives a digging arc—one that is more suitable for over head or vertical welding.

Now it can be understood why the "Shield-Arc" SAE has two controls. One is to vary the open circuit voltage, or the arc characteristics of the welder, and the other is to vary the current for different sizes of electrodes or different sizes of plates. By continuous ranges on both the "Job Selector" and "Current Control" it is possible to completely eliminate any blind spots. No compromise need be made. The exact type of arc and the exact currents can be obtained for every single welding job . . . to suit every operator's individual style or technique of welding.

Instructions to the Student

The student should familiarize himself with this welder by striking arcs with the controls at various positions, noting the wide range of current and arc characteristics obtainable.

Questions for this section are on Page 129; Answers on Page 147.

LESSON 1-B

Object—The Study of Lincoln Junior Welder.
Apparatus—Lincoln "Shield-Arc Jr." Welder, 150, 175 or 200 ampere size.
Material—Scrap sheet—5/32" and 1/8"; 3/32" metal electrode or 3/16" carbon electrode.

The lessons in this book are planned for use with Lincoln 200, 300 or 400 ampere welders D.C. or A.C. In some cases where the electrode specified in the lesson is too large for use with the "Shield-Arc Jr." D.C. Welder or "Lincwelder" A.C. Welder, a smaller electrode should be used. See page 155 for recommended changes.

The ever widening use of arc welding and the development of electrodes for light gauge welding have indicated the need for a machine such as the Lincoln Junior, a machine that would give the same easy stable arc on light gauges with small electrodes as is secured with larger machines on heavier work. The result of Lincoln's effort is the Lincoln Junior. The beginner will find it very easy to handle, and the experienced welder will appreciate its smoothness and that indefinable quality known as "feel of the arc."

This machine is equipped with dual control of welding current or heat. To meet the varied requirements of present day welding it is highly desirable to be able to vary the voltage and current separately. Dual control means that it is possible to get proper welding current at welding voltage practically through the range of the machine in two or more ways. It may be likened to the auto-

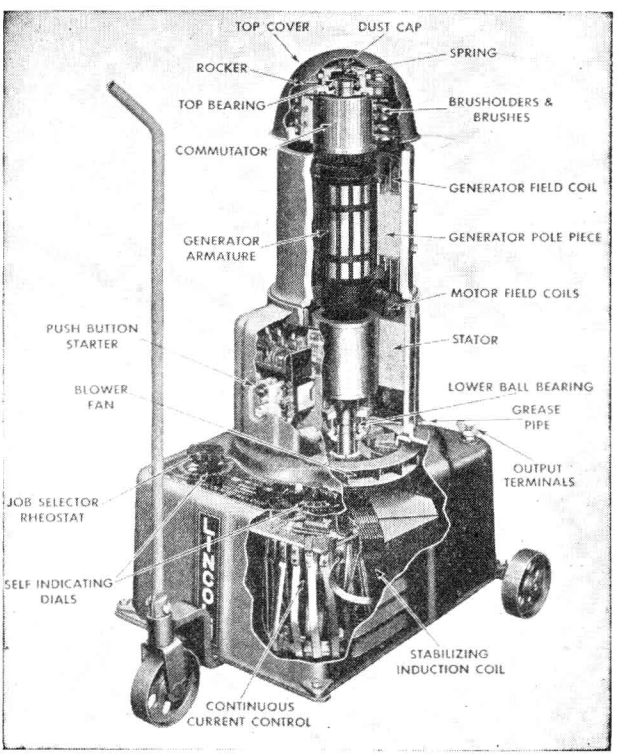

Fig. 1

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