OXYACETYLENE WELDING
An Instructional Manual For Industrial Arts Classes

A Thesis Presented for the Degree of Master of Arts

OHIO STATE UNIVERSITY

by

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The Ohio State University
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Approved by:
Adviser
Air Reduction’s widely known line of welding and cutting apparatus has behind its history of over a quarter of a century, a steadily growing public approval. The complete line is obtainable from conveniently located storerooms throughout the United States. Factory-supervised apparatus repair departments have been established throughout the country, as an added service to Airco customers, so that major apparatus repairs, if required, can be made locally.

The following pages describe those Airco Welding and Cutting Outfits which are most commonly sold by Airco Dealers throughout the country. Also described are various oxygen and acetylene regulators, together with welding and cutting torches and their complete range of tips. From these units you can assemble whatever type of outfit fits your individual requirements better than the regular stock outfits listed.

If you do not wish to buy a whole new outfit at one time you can bring your old one up to date by replacing each unit separately. Trade-in allowances are given on the old apparatus as it is turned in.

In addition to material shown on the following pages, torches, regulators and other apparatus for special production work and for large manifold service are also available from Air Reduction. For complete information regarding this specialized welding and cutting apparatus, as well as gas cutting machines, see your nearby Airco dealer.
FOREWORD

While attending classes and weekly Forum meetings the two writers soon became aware of an atmosphere which prevailed through the Industrial Arts department—it was one of professional growth and leadership. It is with sincere recognition that we wish to ascribe this influence and exemplification to Dr. William E. Warner.

The subject of oxy-acetylene welding was chosen for our thesis study because of our interest in it due to a background of experiences in industry, school teaching, and military service. And furthermore, from the standpoint of teaching we wish to develop a manual of instruction which could possibly be used in the Industrial Arts laboratory.

We wish to recognize the following firms and organizations: Air Reduction Sales Company of New York City for the illustrations; the United States Navy of Washington, D. C. for training and work sheet drawings; Air Reduction Sales Company, Branch Offices of Cleveland, Columbus, and Steubenville, Ohio, for visits and consultations; Globe Stamping and Machine Company, National Carbon Company, and Warner and Swasey Company all of Cleveland, Ohio, for industrial training and employment.

August 1947

JOHN ALLEN KUZMAN
VICTOR KUZMAN
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Chapter I

INTRODUCTION

No student of the oxyacetylene process can be considered versed in his work without some knowledge of the history of his art, the properties and characteristics of the tools and materials, and the practical applications of his profession. It is with this thought that the following definition appears.

Definition of Welding. Welding, as defined by the AMERICAN WELDING SOCIETY (25, p. 8),* is:

The localized intimate union of metal parts in the plastic, or plastic and molten states with the application of mechanical pressure or blows, and in the molten states without the application of mechanical pressure or blows.

In view of this explanation, oxyacetylene welding is a non-pressure process of joining two pieces of metal by fusing or melting their adjacent edges, thus, forming a pool of molten metal which upon cooling forms a solid bond between them.

Forgings of metals and welding were hand processes purely associated with the blacksmith trade, for the

*(1, p. 8) See reference Number 1 in the Bibliography. Similar references occur throughout the thesis.
blacksmith represents one of the oldest metal working crafts. Smith (37, p. 22) in his unit on How To Make a Forged Lap Weld states,

"Welding is the process of uniting two or more pieces of wrought iron, low carbon steel or tool steel. Two pieces of metal can be united with blows of a hammer when each is in a semi-molten or pasty state.

To bring the metals into a prepared welding state, a blacksmith always uses a forge with a clean hot fire as his source of heat. In contrast to this method the oxyacetylene welder employs a flame as a source of heat for joining or fusing metals. The blacksmith is rapidly being replaced by the oxyacetylene welder. In this respect Smith (37, p. 2) in his introduction reports:

"Thirty or forty years ago blacksmiths were found in every hamlet and at almost every crossroad. In engineering shops they were found in considerable number—very large shops employing from fifty to a hundred or more. Today, in the hamlet and small town, the smith's place has been taken by the garage man. In engineering shops he has been superseded very largely by the oxyacetylene and arc welder.

Although the blacksmith has not disappeared completely, still the integrity of his workmanship continues in the hands of the oxyacetylene welder today.

Welding in Industry. Oxyacetylene welding and cutting are recently developed arts, but their uses have
spread throughout industry and the metal working trades. New uses and applications of these processes are being constantly developed to a point where this tool has proved invaluable in production, fabrication, and repair. All common commercial metals are readily fused with this oxyacetylene process, and practically all can be welded. It is widely used in welding of mild steel, wrought iron, black iron, alloy steels, steel castings, aluminum, copper, brass, bronze, nickel, monel, stainless steel, precious and semi-precious metals, or in general, ferrous and non-ferrous metals.

The steel body of an automobile is pressed out in sections. This is an example where welding has played an important part. It is the cutting process in ship building which is used in cutting and beveling ship plate for the welding by the electric arc process. Then, too, welding is used extensively for joining pipe fitting throughout the vessel. One only needs to reflect to this last war, World War II, and think of the many vessels which were entirely built by the welding process. The structural steel tubings in the aviation industry are fastened by the oxyacetylene flame. In the realm of pipe welding such items as oil transmission lines, steam, air, and water lines are welded. The railroads cannot be omitted for large number of welders are employed in the maintenance and repair of car parts and
engines and in the scrapping of old equipment. The many industries engaged in the manufacture of steel barrels, metal furniture, kitchen ware, farm equipment, and other gauge metal products use the welding procedure. Foundry can be mentioned where the risers from castings are cut off. Large expensive castings are being replaced today by parts built from structural steel plates. Buildings, bridges, and hangers are being welded in constantly increasing numbers. Air conditioning and refrigeration surely could not have made the progress without the use of the oxyacetylene process. Today, industry accepts the oxyacetylene flame as the ideal and economical means of making strong and lasting joints.

Welding in the Industrial Arts Laboratory. Many secondary schools are offering welding on a vocational basis in which they seek to provide shop experiences suitable for industrial employment. This report, however, will contend to justify welding as a general education subject through a program in the Industrial Arts Laboratory. There seems to be a strong correlation between the march of civilization and progress in the use of minerals. When man first discovered metals and methods for refining them he soon realized the importance of these new materials, so that from early times metals and their working processes have become
interwoven with the progress of civilization. Historians have designated periods of history by the name of the dominant minerals of that period, such as "The Bronze Age" and "Iron Age". Man had progressed by the nineteenth century to a point where he relied almost completely on the metals already developed. Certain metal working processes were developed at this time. The blacksmith represents one of the oldest metal working crafts and it is from the smiths' forge that the process of Forge Welding derives its name. The blacksmith upon heating the metal to a plastic state hammered or joined the metal, and hence, this process is classified as Pressure Welding. It was in the twentieth century that metal workers and industry were provided with a tool with which metals could readily be joined and severed—this tool was the oxyacetylene process. And thus, metals, heat and flame, chemistry, and the related technology seem to be the basis for the industrial development of the nation.

The subject matter for industrial arts comes out of the industrial life of a nation. According to Bonser (11, p. 5),

Industrial Arts is a study of the changes made by man in the forms of materials to increase their values, and of the problems of life related to these changes.
The Federal Committee on Industrial Arts, in their initial bulletin (36, p. 24), make two concrete suggestions in regard subject matter content by saying that the program of Industrial Arts should provide for:

1. Acquainting the student with the way industrial and commercial enterprises are organized and operated.

2. Tracing materials from source to completed objects.

According to the AMERICAN VOCATIONAL ASSOCIATION COMMITTEE (38, p. 14) in the first of the twelve listed objectives for Industrial Arts Education we read as follows:

To develop in each pupil an active interest in industrial life and in the methods of production and distribution.

How can these objectives be obtained? Only through a program of Industrial Arts education whose functions can be stated as listed according to the Ohio School Standards (31, p. 1).

The Orientation Function: Industrial arts helps the secondary school pupil achieve orientation in an industrial society by exploring many types of tools, materials, processes, products and occupations. Manipulation is only a means for promoting other ends. Habits and skills derive their value from appropriate use. The emphasis is rather upon attaining a pattern of knowledges, attitudes, habits, skills and under-
standings essential to individual and group welfare in a technological society. One of the outcomes of the orientation function is occupational guidance.

**Technical Function.** Industrial arts should provide as many opportunities as possible for pupils to spend at least a year in any phase of work where orientation may help to define specialized interests that can be pursued with profit. The opportunity for example, should be provided for a pupil to delve into the intricacies of cabinet or furniture making, electrical communication and power, lighting, automotives, printing a monograph, making a cabin or a boat including drawing the design and writing the specifications, designing and making a small machine, studying the occupational possibilities of certain local industries or any similar problem or group of related problems in one or more areas of the industrial arts program.

**The Recreational Function.** Industrial arts also provides a wide variety of useful, wholesome and enduring leisure time interests and activities. Collection and appreciation is involved in addition to manipulation. The importance of this function is increasing. There is now almost as much time for leisure as for labor and sleep together. Increased time affords not only an educational opportunity but it also becomes a liability and a responsibility with which the school must cope.

**The Consumer Function.** Industrial arts also helps the individual develop intelligent attitudes and understandings concerning the selection and use of the products of industry. This involves studies and experiences covering a range of topics and problems all the way from the production of raw materials, through the processes and problems involved in their manufacture, to the distribution of finished products and their use by the consumer. It should help him achieve consumer literacy since he needs to live intelligently in the midst of an involved technology.
The Social Function. Industrial arts, because of its nature, is also able, through activities in the shop or laboratory as well as outside, to help develop desirable social habits and attitudes. The program is concerned, for example, with helping pupils understand and formulate wholesome opinions toward such things as integrity of workmanship, sanitation, housing, wages and hours of labor, safety, preservation of natural resources or any other related social problem.

The Cultural Function. Industrial arts the individual enjoy a finer culture as regards materials in an involved technological society. This means helping him develop and use his material inheritance. For example, the pupil can learn to know style or design in architecture, furniture, rugs, pottery, silverware, glass, dress, china, printing, machinery and other items of common use to appreciate the forces that have influenced them. With a cultured taste, he is prepared to surround himself with those things from which he can derive life-long satisfaction.

A course based upon these objectives surely would fit into the program of general education as typified by our democratic and industrial society. The subject of oxyacetylene welding cannot be disassociated from the field of metals and their respective fabrications and production. Thus, its logical place and inclusion would be in the manufacturing division of the general shop.

Limits of the Study. Welding in general has undoubtedly made significant contributions to progress and continues to do so. Because of the usefulness and its adaptation to man, a great industry has been created, ever expanding through scientific research and thereby involving
wide range of human activities. Out of such activities comes the material for the subject matter of industrial arts, and consequently a study of oxyacetylene welding may be considered appropriate as content for industrial arts. The general field of welding is immense and involves other processes, all of which places a limit on the amount of time and search involved. A mere mention of other processes of welding is included here for distinction purposes only. They are: electric arc welding, electric resistance welding, which includes butt, line, percussive, and spot welding; thermit welding and the more recent heliarc welding. Oxyacetylene welding has been chosen for its appropriateness as subject matter for industrial arts on the secondary level. This study will therefore be concerned principally with the history, basic principles, design and function of equipment, safety, organization, and instruction of the oxyacetylene welding process.

Purposes:

1. To orient the reader in the subject of welding
2. To report its history and principles
3. To show the design and functions of equipment
4. To provide instruction for organization and operation
5. To list safety precautions
6. To develop a work sheet manual for industrial arts
7. To organize and report a course

Techniques:
1. Review literature
2. Examine industrial bulletins
3. Confer with industrial representatives
4. Observe industrial practice
5. Analyze existing instructional materials
6. Adapt military training and experience
7. Manualize resulting data

The opening chapter defined oxyacetylene welding and pointed out its many industrial applications. It also presented a definition of Industrial Arts, its philosophical background in relation to modern democratic and industrial society, and the justification of oxyacetylene welding as part of general education on the secondary level.

The next chapter will reveal to the reader the historical development and the basic principles of oxyacetylene welding.
Chapter II

HISTORY AND BASIC PRINCIPLES OF WELDING AND CUTTING

The use of the oxyacetylene flame in welding is the outcome of the discoveries of many experimenters. Oxyacetylene welding and cutting have been brought to their present state of development within the present century.

This chapter will reveal the historical development and the principles of this study. Miller in his book (28, p. 3), states:

The process of autogenous welding by means of the oxyacetylene torch or blowpipe dates back to the year 1900.

Furthermore, The Linde Air Products Company (40, p. 3), state:

Early in the twentieth century, metal workers and manufacturers were provided with a tool with which metals could be readily joined, with which steel and iron could be easily severed; a tool which has since proved invaluable in production, fabrication and repair—the oxyacetylene process.

One becomes acquainted from the above with the inception of this process and its time. The early development of the oxyacetylene process can be better brought out by presenting a review of a lecture as published by the Air Reduction Sales Company (1, p. 4). The lecture reports
that the oxyacetylene torch is accredited to two Frenchmen, Fouche and Picard, who made the first commercial torch in Paris in the year 1900. In 1895, Le Chatelier, a French chemist discovered that the combustion of acetylene with oxygen produced a flame having a temperature far higher than that of any gas flame previously known. In his paper on the temperature of flames at the Academie des Sciences, he stated that acetylene, burned with an equal volume of oxygen, produces a temperature of 1000 degrees C. higher than oxy-hydrogen flame. The primary combustion of acetylene with equal volume of oxygen yields hydrogen and carbon monoxide, both which are non-oxydizing in character or reducing agents. This double property makes the use of acetylene of great value for the production of high temperatures. These two gases then burn in the envelope of the flame, uniting with oxygen from the surrounding air to form water vapor and carbon dioxide, the final product of combustion. The oxyacetylene flame has a temperature estimated at 6300 degrees F.

Acetylene. The discovery of acetylene is an interesting chapter in the development of the acetylene process of welding. Calcium carbide is necessary for the manufacture of acetylene. Quoting Mackenzie and Card (25, p. 50) as they reveal the early discovery of calcium carbide:
As early as 1836 Edmund Davy, an English chemist observed that a by-product which he had secured incidently to the production of metallic potassium, was capable of decomposing water with the evolution of a gas which contained acetylene. In 1882 Woehler, announced the discovery of the preparation of acetylene from calcium carbide which he had made by heating to a very high temperature a mixture of charcoal with some alloy of zinc and calcium. The product could decompose water, like Davy's compound and yield a gas containing acetylene. Thus the phenomenon which had been observed but not understood by Davy was explained and published by Woehler, and to him belongs the honor of the discovery of calcium carbide and of acetylene.

And nearly for thirty years calcium carbide and acetylene seem to have been practically forgotten. Acetylene continued to be made by the early tedious methods, and there was no commercial method devised for its production. Quoting MacKenzie and Card (25, p. 50) again, who state:

It was through the instrumentality of the electric furnace that the possibility of calcium carbide as a commercial product was revealed to Thomas L. Willson, an electrical engineer at Spray, North Carolina. In May of 1882 Willson was conducting experiments with a view to the preparation of metallic calcium, for which purpose he employed an improved Heroult electric furnace with a current of 2000 amperes and 36 volts, operating upon a mixture of lime and coal tar he secured a melted mass of dark color, which on cooling became solid and brittle. Willson is said to have discarded this product as it was clearly not the material for which he was searching—metallic calcium.

And now comes an interesting story. The quotation continues:
It was thrown into a neighboring stream, when to the astonishment of those who saw it, there was suddenly liberated a great quantity of gas which, on being kindled, burned with the now familiar, bright but smoky flame, and gave off quantities of soot which showed that it was not hydrogen, which would be liberated from metallic calcium and water, but a rich hydrocarbon gas. The smelt was repeated and the product submitted to analysis, which demonstrated that the solid substance contained calcium carbide, and the gas, acetylene.

Thus, this interesting report reveals the discovery of calcium carbide and acetylene. Calcium carbide is no new thing since it has been known for a greater part of a century, but the possibility of its manufacture in quantity dates only from these experiments at Spray, North Carolina, 1892.

In a review of lesson one on acetylene, Plumley (33, p. 1) and Chapter III of The Oxyacetylene Handbook (40, p. 30) acetylene is said to consist of 93 per cent and 7 per cent, which is the highest percentage of carbon content of all the gaseous hydro-carbons. In addition, this gas possesses endothermic properties, which means, that it absorbs heat during production and liberates heat when it is decomposed. For these reasons, the oxyacetylene flame is the hottest flame known and is exceeded only by the heat in an electric arc.

When carbide is dropped into water, a reaction
occurs that causes bubbles of gas to rise, and this gas is known as acetylene. It has a peculiar odor and burns with a smoky flame.

Acetylene gas is stored safely by being pumped into special steel cylinders which are loosely filled with a porous material. The fine pores are then filled with acetone, a liquid chemical having the property of dissolving or absorbing many times its own volume of acetylene. In such cylinders acetylene is perfectly safe and will not change its nature.

Where large amounts of acetylene are required it is most economical to make the acetylene by a suitable generator. Acetylene generators of various capacities are available, and so, when installing and operating acetylene generators, the manufacturers instructions should be followed exactly. An acetylene generator of the carbide to water consists of a water compartment on top of which is a carbide hopper with an automatic feeding device, a pressure gauge, safety valve, and a cooling and cleaning mechanism through which the generated gas must pass on its way to the torch. A pound of carbide will produce about 4.5 cu. ft. of acetylene. As the carbide drops into the water a considerable amount of heat is given off in this reaction. Most commercial generators require a gallon of water for each pound of carbide.
Acetylene Generators

Fig. 1

Fig. 2
Oxygen. Oxygen, according to a review of Lecture No. 3 by Air Reduction Sales Company (1, p. 14), was recognized by its properties as far back as the eighth century among the Chinese who knew the active components of the air combined with some metals, with sulphur and with charcoal and that this active component could be obtained pure from saltpeter. Oxygen is the life and fire sustaining element of the air which we breathe. If all oxygen were removed from the air all life would cease to exist. Fire cannot burn without it. About one-fifth of the earth's atmosphere is composed of oxygen. It is a colorless, odorless, and tasteless gas that supports combustion, but in itself it is non-inflammable.

MacKenzie and Card (25, p. 128) report:

The discovery of oxygen as an element was made by two chemists, Priestly and Scheele, working independently and without knowing of each other's endeavors.

For the welding trade the principle value of oxygen lies in the fact that it will support combustion. Various methods have been perfected for the commercial production of oxygen. Of importance are the following two processes: the electrolytic and the liquid air.

The Welding Encyclopedia (25, p. 128) describes these methods thus:
In the electrolytic process a direct electric current is passed through water, to which a small quantity of acid or alkali, such as caustic potash, has been added. The electric current causes a decomposition of the water into its chemical elements, oxygen and hydrogen, the oxygen being liberated and accumulated at the positive pole, and the hydrogen at the negative pole.

In contrast to the above method the liquid air process is based upon the idea of separating the various gases that constitute the air, by means of a very low temperature and the consequent liquifying of these gases. The quotation continues:

In all rectification processes, the separation is accomplished by means of the interaction between a descending stream of liquid and an ascending stream of vapor in intimate direct contact with each other. The liquid as it descends becomes richer in the constituent having the higher boiling point, while the vapor as it ascends becomes richer in the constituent having the lower boiling point. In case the mixture treated in a rectification column is liquid air, the descending liquid stream becomes ultimately almost pure oxygen, while the vapor stream increases its nitrogen percentage as it ascends.

The practical application of this principle is much more complicated than a mere statement of the principle itself.

**Welding Torch.** With reference to the information as expressed in Lecture No. 5 of the Air Reduction Sales Company series (1, p. 22) the following summary is presented: The purpose of the welding torch is to provide a
means for mixing approximately equal volumes of oxygen and acetylene and to provide sufficient quantity of gas mixture at the torch tip so that when ignited a flame will be produced.

The forerunners of the oxyacetylene welding torch are the simple blowpipe and Bunsen burner. The simple blowpipe, used by jewelers and watch makers, is considered the oldest ancestor of the torch. The ordinary blowpipe is a simple tapered tube curved at the tip, through which a workman blows against an alcohol flame to increase its intensity. These have been used by the early workers in gold, silver, and brass to melt their solders. In the Bunsen burner part of the air necessary for combustion is injected or sucked into the gas stream. The mixed gas and air flow to the opening or tip of the burner where they ignite. It is this premixing of air and gas that results in a blast flame of high temperature.

The oxyacetylene welding torch follows the Bunsen burner principle of premixing a combustable gas with oxygen, but differs from the Bunsen burner in that it uses pure oxygen in place of air. The torch is divided in two parts, the torch body and the tip. The body contains the hose connections and the adjustment needle valves.

Cutting Torch. The art of cutting metals with a combination of gases and the torch is fairly modern.
MacKenzie and Card (25, p. 308) report:

The first reference to the art was made in 1888 in a paper read by Thomas Fletcher in England. A German patent was issued to Herman A. E. Menne in 1901 on the use of oxygen for cutting, or as he termed it "melting".

In September, 1906, a United States patent was issued to Felix Jottrand, a Belgian, on the process to cut plates, pipe and other metal articles with a device using a mixture of oxygen and hydrogen, or other combustable gas, together with a jet of oxygen. It has been claimed that John Harris, of Cleveland, Ohio, cut pieces of steel by this method in 1904.

From this early development the technique for cutting steel developed rapidly, and it was not long before oxyacetylene cutting became widely used in the metal working industry.

**Principles of Welding and Cutting.** Oxyacetylene welding is a non-pressure process wherein the heat is obtained from an oxyacetylene flame, formed by the combustion of equal amounts of oxygen and acetylene. The welding is accomplished by a torch which is so designed that an operator has full control of the tip flame. In this operation the edges of the metal are fused or melted down with the acetylene flame which involves various torch manipulations. Filler materials or welding rod may or may not be used in the completion of the weld.

Oxyacetylene cutting of ferrous metals is the process of preheating the metal to be cut to its kindling or
ignition temperature, and then rapidly oxidizing it or burning away by means of a closely directed stream of oxygen. The process is primarily a chemical one, based on the remarkable chemical affinity of oxygen for ferrous metals, when the latter are used to or above their kindling temperature. Only the metal in the direct path of the oxygen jets is acted upon. This torch consists of a handle, connecting tubes and hose connections. The oxygen furnished to the preheating flames is regulated by a preheat valve on the side of the handle, while a high pressure oxygen valve operated by a trigger controls the cutting oxygen. Each manufacturer has his own design, construction, and size, and hence, one should follow the manufacturer's specifications for operation.

The names of early personalities appear in respect to the discoveries of the gases and the development of the welding torch. Chemical properties and the reaction of both oxygen and acetylene are reported and their use in oxyacetylene welding and cutting. Reference is made to the manufacture, filling, and distribution of oxyacetylene cylinders, and to the basic principles of welding and cutting.

The next chapter describes the physical plant through which the basic principles are effected.
Chapter III

DESIGN, MANUFACTURE, AND FUNCTION OF EQUIPMENT

A report on oxyacetylene welding is incomplete without some knowledge of the functioning parts. The information and description which follows is the result of personal industrial experiences and training, and also findings in manuals of instruction and catalogs of Air Reduction Sales Company, The Linde Air Products Company, and the Burdett Oxygen Company.

**Oxygen Cylinders.** The bulk of commercial oxygen is supplied to consumers in drawn seamless steel cylinders of 110 or 220 cu. ft. capacity both charged at a pressure 2000 psi. (meaning pounds per square inch) at 70 degrees F. The standard 220 cu. ft. tank is 54 inches high, 9 inch outside diameter and has a wall thickness of .260 inches. Oxygen cylinders are tested with water before consideration of use to 3360 psi. The pressure of oxygen in cylinders varies directly with the temperature. The pressure increases when the temperature increases and visa versa. As a precaution, cylinder valves are double seated and should be open all the way to seal the valve stem. The valve has a safety fuse plug. Oxygen cylinders should be stored in rooms where an even temperature is maintained and cylinders should be kept free from all oil and greases.
Commercial oxygen cylinders are under the Interstate Commerce Commission regulations and loaned by the companies to the private customers for a period of thirty days without charge after which there is a demurrage. All oxygen cylinders may be used until quite empty of gas and disconnected and marked "MT" for empty. A protective cap is screwed on and the cylinder is thus prepared for shipment and refill to the company. Of mention, these cylinders are drawn from a single plate of grade steel and carefully heat treated to develop utmost strength and toughness. See Fig. 3.

Acetylene Cylinders. Acetylene cylinders are similar in design to the oxygen cylinder, but are only 45 inches tall and 12 inches in diameter and have 1/4 inch seamless wall. The capacity of the acetylene cylinder is approximately 300 cu. ft. The cylinders are pressed steel but the bottom is left open during the manufacturing process to permit the cylinder to be filled with one of several porous substances such as, charcoal, asbestos, balsa wood, and cement. This can generally be compared with swiss cheese with many small holes.

After the bottom has been welded in place the cylinder is filled with Acetone (a liquid which has the ability to dissolve approximately 25 times its own volume for each pound of pressure). The porous material in the tank
Oxyacetylene Complete Unit

Fig. 3

Regulators

Fig. 4

Mobile Truck

Fig. 5
will absorb the acetone and the acetone in return will
dissolve the acetylene as it is compressed into the cyl-
dinders. See Fig. 3.

The valve does not have to be of the high pressure
type as a full cylinder will give a reading of approxi-
mately 250 lbs. It is generally of the screw type and is
recessed so as to require a special wrench to open the
stem. This is so that it will not be open by accident,
and the gas allowed to escape. (1 per cent acetylene will
ignite in the air very readily).

The cylinder is designed for a cap to protect the
valve from damage when not in use, and one is cautioned al-
ways to replace it. Fusible plugs in both the bottom and
the top of each cylinder are incorporated as safety factors.
An acetylene cylinder weighs approximately 16 lbs. more
when full than when empty. When empty it weighs approxi-
mately 215 lbs. If the acetylene is drawn off too fast it
will tend to draw off acetone with it. Therefore, not more
than one-seventh of its volume should be used per hour.

Regulators. Regulators are so designed as to re-
duce the cylinder pressure to a desired working pressure,
and thus assures a perfectly steady and uniform flow of
gases reaching the blowpipe. A regulator consists of a
brass metal housing which encloses all the working parts
with the exception of the gauges which are attached on the
outside. In terms of manufacture there are two types of regulators: (1) single stage and, (2) two stage. See Fig. 4.

Acetylene regulators differ from oxygen regulators only in that they do not have to withstand as high pressures as either the high pressure or working pressure stages and, hence, the springs supplied in them are less in tension. In principle, however, the regulators are identical. The physical mechanism of the regulators centers around the functions of a flexible diaphragm and the tension of a spring.

The general design of the regulators involves two gauges on the body, one showing pressure in the cylinder and the other working pressure that is being supplied to the torch. Adjusting the pressure in the working pressure stage is accomplished by a hand screw at the front of the regulator. When the pressure adjusting screw is turned out (counter-clockwise), the valve mechanism inside the regulator is closed and thus there is no flow of any gas in the torch. In the act of turning the pressure adjusting screw (clockwise), the screw stem presses against the regulating mechanism, opens the valve and allows passage of gas through the torch at the pressure shown on the working pressure gauge. The reading graduations on the dials of the gauges differ.
Oxygen regulators are designed so that the high pressure side of the regulating mechanism will take care of the full cylinder pressure. Cylinder pressure gauge graduations read from 0 to 3000 lbs. psi. In contrast the working pressure gauge graduations are registered from 0 to 100 lbs. psi.

Of importance, one must note the difference of the dial readings on the acetylene regulator. The acetylene cylinder pressure gauge registers a reading from 0 to 350 lbs. psi. The working pressure gauge is usually set to 30 lbs. but only 15 lbs. reading graduation is indicated. The reason for the latter is that acetylene should never be used above 15 lbs. psi. All acetylene gauges have vent holes on the side of the case to relieve any abnormal pressure.

Oxygen and Acetylene Hose Line. Hoses are manufactured of rubber in several sizes and shapes, either single or twin. It must be remembered that the oxygen hose is green, and is fitted with connections and swivel nuts. The acetylene hose is red and is fitted with connections that can only be attached to the acetylene regulator and acetylene needle valve on the blowpipe. As a precaution all new hose should be blown out before using because of the powder lining. All welders seem to prefer the twin molded hose. See Fig. 6.
Oxyacetylene Welding Torch. The oxyacetylene torch is a tool for combining oxygen and acetylene in nearly equal volumes, mixing and burning them at the end of a tip. Hence, it is a tool which gives the operator complete control over the size and type of flame desired. It is quite true that designs vary, but all types have certain fundamentals characteristics. The welding torch has two tubes, one for oxygen and one for acetylene which feed into a mixing chamber. It has also a handle and two needle valves for control and adjustment of the flame. A variety of welding heads or tips are supplied with each blowpipe. See Fig. 7.

There are two types of oxyacetylene welding torches, namely, the low pressure, or injector and the equal pressure type. In the injector type the acetylene is delivered to the torch at a pressure of only a few ounces. The oxygen at a higher pressure passes through the injector and expands rapidly into the mixing chamber. This action now forms a suction and draws in the acetylene at a constant ration. The rapid expansion at high velocity of the oxygen sets up a whirling motion and produces an intimate mixture of the oxygen and acetylene.

In the medium pressure torch both the oxygen and acetylene are supplied to the torch at a constant pressure and which are controlled by means of regulators and slight adjustments of the torch valves.
Fig. 6

Hose

Fig. 7

Welding Torch

Fig. 8

Wrench

Fig. 9

Tip Cleaner
Welding Tips and Tip Cleaners. Tips are made of seamless copper and are provided in a wide variety of sizes. Practically all welding torches are provided with a series of interchangeable heads or tips of different sizes so that the same handle can be used on a wide range of operations. See Fig. 9.

A tip cleaner when used to clean the orifice of a tip should be moved up and down and should not be twisted.

Wrenches. Open end wrenches for setting up regulator nuts, connecting hose, and changing torch tips are necessary tools of every welder's equipment. Always use a wrench that is furnished by the manufacturer or one that fits exact, all of which will prevent the nut or parts from becoming rounded off or damaged.

Sparklighter. This tool is an indispensable accessory for welding and cutting, because it provides a safe, convenient, and instant means for lighting the torch. Friction lighters should always be used instead of matches. See Fig. 10.

Goggles. Goggles should be worn at all times while welding to protect the eyes from reflected heat and from flying sparks. See Fig. 11. Lenses are available in light, medium and dark shades.

Gloves. Gauntlet type gloves of leather, asbestos or other non-burnable material should be worn by the
Sparklighter

Fig. 10

Goggles

Fig. 11

Leather Gloves

(A)  (B)

Fig. 12
operator to protect their hands against contact and radiation burns. See Fig. 12.

Operator's Dress. The three most essential items of the operator's dress are the goggles, the gloves, and suitable coveralls or aprons.

Welding Fluxes. A flux is essentially a deoxidizing agent and is used to clean the metal of all impurities. Fluxes are used in welding cast iron, brass, bronze, aluminum, nickel, monel, and the non-ferrous metals. It is necessary that the welder learn to apply flux properly. Intimate mix, proper proportions, and purity are essential for the best results. It is well to remember that it is best to follow the manufacturers' recommendations regarding fluxes and rods.

Welding Rods. In general, small welding rods are used for light welding and larger rods as the work becomes heavier. Rods come in the following sizes: 1/16 inch, 3/32 inch, 1/8 inch, 3/16 inch, and 1/4 inch. Use of inferior or unsuitable welding rods should be completely avoided. Again, it is best to follow a reputable manufacturer's make. Mild steel rods have a copper coating to prevent oxidation. The filling material or welding rod as a rule should be of nearly the same chemical composition and physical characteristics as the parent metal. A low carbon rod is generally used when welding low carbon steel, cast iron
rods on cast iron, copper rods with copper, aluminum rods with aluminum, etc. When welding dissimilar metals the welding rod as a rule is of the metal having the lower melting point. Oxyacetylene welding rods are classified ferrous and non-ferrous.

**Mobile Trucks.** A mobile truck comprises of a welded steel frame with wheels attached for ease of transporting the welding unit. The truck has chains for securing cylinders in place.

**Welding Table and Tools.** A welding table consists primarily of an angle iron welded frame and firebrick. The size of a table top made vary, but its height should be 28 inches or 30 inches.

A welder's shop tools should consist of the following: ball peen hammer, cold chisel, center punch, wire brush, try square, tongs or pliers, steel V blocks, hacksaw, steel rule, soap stone pencil, note book, scribes, and lead pencils.

This chapter has reported a description and the related information of each individual part of the oxyacetylene unit in terms of design, manufacture, and function.

The following chapter enlightens the reader in the instructions for organizing and operating a welding unit.
Chapter IV

INSTRUCTIONS FOR ORGANIZING AND OPERATING WELDING AND CUTTING EQUIPMENT

The purpose of this chapter is to provide instruction for organizing and operating a welding unit. The instructions which follow are derived from actual teaching experiences at West High School, Cleveland, Ohio, Norwalk High School, Norwalk, Conn., and from training received in the United States Navy, Chicago, Illinois.

Considerable thought should be given in the setting up of a welding outfit from its physical point of view and also of the very exact knowledge involved. The learner should practice setting up and connecting the torch, hose and regulators in a sequential manner, because this procedure follows a logical order, assures safety, and eliminates unnecessary movements. The following procedure of these steps is necessarily somewhat general in character because of the variation of the particular type of equipment used.

**Attaching Oxygen Regulator to Oxygen Cylinder**

1. Open slightly the oxygen cylinder valve. This is known as "cracking" the cylinder.
2. Connect the oxygen regulator to the oxygen cylinder. Note: Oxygen regulators and cylinder valve outlets have right hand thread connections.

3. Loosen or turn out the pressure adjusting screw of the regulator.

Attaching Acetylene Regulator to Acetylene Cylinder

1. Open slightly the acetylene cylinder valve. This is known as "cracking the cylinder.

2. Connect the acetylene regulator to an adapter and then to the acetylene cylinder. Note: Acetylene regulators and cylinder valve outlets have left hand threads.

3. Loosen or turn out the pressure adjusting screw of the regulator.

Connect Hose to the Regulators and to Blowpipe

1. Connect the green hose to the oxygen regulator.

2. Connect the red hose to the acetylene regulator.

3. Open the cylinder valves slowly.

4. Blow out the hose by turning in the regulator screw and release regulator.
5. Connect the green hose to the needle valve of the torch marked "Ox".

6. Connect the red hose to the needle valve of the torch marked "AC".

7. Attach the proper head and tip to the torch body.

**Adjust Oxygen and Acetylene Working Pressure**

1. Open the oxygen torch needle valve and adjust the oxygen regulator to the desired working pressure.

2. Close the acetylene torch valve and adjust the acetylene regulator to the pressure desired.

3. Test connections for leaks with soapy water or soap suds.

**Light Blowpipe and Adjust Flame**

1. Open the oxygen needle valve on torch just slightly.

2. Open the acetylene needle valve on torch slightly also.

3. Light the torch with the spark lighter.

4. Open oxygen needle valve for a flame. See Fig. 13.
   a. Excess Acetylene Flame. The acetylene flame is produced by burning pure acetylene with air. It is recognized by a large intensely
These natural color photographs will give the student an accurate guide for adjusting the oxyacetylene flame. Correct flame adjustment is so vital to successful welding that the best manipulative skill is lost unless the flame adjustment is correct.
white cone, smoky at outer end, and obtained when first lighting torch.

b. Carbonizing Flame. Carbonizing flame is produced by burning an excess of acetylene. It can easily be recognized by the feathery edge of the white cone.

c. Neutral Flame. Neutral flame is produced by burning the correct mixture of oxygen and acetylene. It has one clear, well defined white cone surrounded by a nearly colorless flame of large volume.

d. Oxidizing Flame. Oxidizing flame is produced by turning on excess oxygen. It can be recognized by its shorter envelop of flame and the small pointed white cone.

**Shutting Down Equipment**

1. Close acetylene valve on torch.
2. Close oxygen valve on torch.
3. Close acetylene cylinder valve.
5. Open torch acetylene valve to drain the line; release the adjusting screw on the acetylene regulator then promptly close torch acetylene valve.
6. Open torch oxygen valve to drain the line; release the adjusting screw on the oxygen regulator then promptly close torch oxygen valve.

7. Secure hose line in its proper place.

8. Double check all cylinders and see that all valves are closed.

**Backfires and Flashbacks.** Improper operation of the torch and the disappearing of the flame with a loud snap or pop is considered as a "Backfire." Occasionally particles of molten metal will stick to the nozzle of the torch or the operator will allow the tip to touch the surface of the metal and cause the torch to backfire. Lighting the torch with a sub-normal pressure in one hose and a normal or excessive pressure in the other hose may be another cause. Other causes of backfiring are loose internal and external tips or dirt on the tip seat. A "Flashback" occurs when the flame burns back inside the torch and is associated with a hissing sound.

To avoid backfires and flashbacks two conditions of lighting and adjusting should be observed: (a) starting up torch on new cylinders; (b) relighting the torch after having been in use. Sometime it is necessary to cool the torch by plunging it into water and then relighting it.
Specific instructions for organization and operation of welding and cutting were presented. The various flames were described and referred to the flame adjustment illustration.

The chapter on safety precautions follows.
Chapter V

SAFETY PRECAUTIONS FOR INSTALLATION AND OPERATION OF OXYACETYLENE OUTFITS

The subject of safety becomes paramount in the mind of an instructor especially when working with youngsters in an Industrial Arts laboratory. Certain dangers and hazards are inherent or incidental to every trade, industry, and profession. Welding or cutting is not particularly dangerous but still common sense precautions must be taken and enforced. And so, efficiency and safety in the use of oxyacetylene process for welding and cutting rather harmonize with careful observance of operating procedures, precautions, and safe practices.

The following suggestions and recommendations for safe practices for handling oxyacetylene equipment appear from Precautions and Safe Practices (41, pp. 9-55) and from Welding and Cutting Apparatus (2, pp. 57-63).

**General Rules for Handling Cylinders**

1. Handle with care and never drop cylinders nor permit them to be struck violently or abused.
2. A cylinder should be stored or used in safe places.
3. Cylinders should be kept away from any school heat generating device.
4. Never use cylinders as supports or rollers at any time whether empty or full.

5. Cylinders should be well secured while in use.

6. Never allow cylinders to come in contact with any electrical equipment.

7. Use only approved cylinders carrying Interstate Commerce Commission markings.

8. Close valves before shipment. See that protective caps for cylinders are replaced before shipping empties.

Use and Storage of Oxygen Cylinders

1. Always refer to oxygen by its full and proper name, "Oxygen".

2. Keep oxygen cylinders, valves and regulators, gauges and fittings from oil or grease.

3. Do not handle oxygen cylinders or apparatus with oily or greasy hands.

4. Never interchange oxygen regulators, hose, or other appliances with similar equipment intended for use with other gases.

5. Open oxygen cylinder valve slowly at first and then all the way after a pressure reducing regulator is attached.
6. Never attempt to tamper or repair oxygen cylinder valves.

7. Do not use a wrench or hammer to open oxygen cylinder valves.

8. Do not store cylinders near inflammable material, especially oil, grease, or any substance likely to cause or accelerate fire. Oxygen is not inflammable, but supports combustion.

9. Do not store reserve stocks of cylinders containing oxygen with reserve stocks of cylinders containing combustible gases. They should be separately grouped.

10. Always store all cylinders in a cool and dry place.

Use and Storage of Acetylene Cylinders

1. Always refer to acetylene by its full and proper name, "Acetylene" and not, by the word "Gas."

2. Remember acetylene differs from city gas or furnace gas.

3. All acetylene cylinders should be used and stored in an upright position.

4. Avoid using a cylinder that is leaking acetylene.

5. Avoid dropping, knocking, or any abuse of acetylene cylinders.
6. Turn the acetylene cylinder so that its valve outlet will point away from the oxygen cylinder.

7. Do not open cylinder valve more than one full turn.

8. Always use the special T-wrench for opening and closing the cylinder valve.


10. Never test for acetylene leaks with an open flame, but use soapy water or suds.

11. Always store acetylene cylinders in a cool and dry place.

12. Never interchange acetylene regulators, hose, or other appliance with similar equipment intended for use with oxygen.

13. The cylinder should never be on its side, but always should be placed in an upright position to prevent the escape of acetone.

Overall Safety Recommendations

1. Always see that hose is securely connected before using equipment.

2. Always wear goggles with a dark lense when working with a lighted blowpipe.

3. Do not use matches for lighting torches. Use a spark lighter.
4. Always use the proper sized tip and proper gas pressures.

5. Never release acetylene where it might be the cause of a fire or explosion.

6. Avoid any experimentation with regulators or blow-pipes.

7. Avoid using the tops of cylinders or regulators as pedestals for securing equipment.

8. Always be careful when working in a confined space.

9. Use designated operator's dress while welding or cutting.

10. Always remove all inflammable substance from welding area.

11. While flame cutting, protect the cylinders, legs, hose, and feet.

12. Stubby ends of welding rod should not be placed on wooden floors.

13. Use correct oxygen pressure when cutting.

14. Always be aware of the possibility of a fire when welding or cutting.

15. Be prepared to extinguish any fire promptly.

16. Always try to be alert and intelligent while on the job.
The following chapter now presents a review of the fundamentals and also a series of exercises wherein the beginner can apply the fundamentals in the actual practice of welding.
The purpose of this chapter is to provide instruction in the manipulation of the torch and rod, in bronze welding of steel and cast iron, and in the cutting process; also, to develop a series of work sheets and exercises for industrial arts. Sources for this material are derived from consultations and visits to industries, from training, and from school teaching experiences—all of these sources being earlier acknowledged in the foreword.

After the beginner has learned how to light the torch and learned to adjust the flame properly, he is now ready to begin practice welding.

**Torch Position.** The torch should be grasped in the right hand so that the fingers and thumb are directly behind the flame adjusting valves. The torch is so constructed that it balances properly when grasped at this point, and will not tire the welder when welding over a long period of time.

**Angle of Torch.** The torch head should be inclined at an angle of about 45 to 60 degrees to the plane of the weld. If the angle of the head is too great, the molten
metal will be blown ahead of the welding area and will adhere to the cold sides of the weld. On the other hand, if the torch head is inclined at a degree near the vertical, the secondary flame will not be fully utilized for pre-heating the metal ahead of the actual welding area.

**Direction of Torch.** In order for the welder to have relative ease and speed, the torch should travel from right to left slowly in a zigzag path.

**Movement of Torch.** Continue a zigzag motion and keep the white "neutral" cone just about 1/16 inch to 1/8 inch above the surface of the plate until a puddle is formed. The formation of the puddle will occur almost instantly, appearing in a circular molten state. The rate of welding progress is determined by the puddle. You cannot weld faster than the advance of the puddle; nor can you weld much slower because if the advancement of the torch and puddle are stopped, the hot metal will drop through.

**Welding Rod Position.** After the beginner has mastered the various motions of the torch, he will now properly introduce the welding rod into the weld in such a manner that the advance of the torch will not be delayed. The rod should be held in an inclined position and almost at right angles to the welding tip. If this angle is adhered to the proper quantity of rod will be added at the right time.

**When to Add Rod.** Before adding the rod, the welder
must be cautious, constantly watching the edges of the weld and determine whether the edges of the weld are in their proper state of fusion to receive it. If the metal is cold the added rod will simply cause adhesion, and not a true fusion. It is therefore necessary to produce equal fusion at the edges of the weld with that of the rod by correct motion of the torch.

**How to Add Rod.** After the molten puddle is formed the welding rod is lowered with the left hand into the puddle until it is in contact with this molten mass. When in this position, fusion is produced by the directed flame of the torch. After this process is mastered speed and relative ease of advancing of the weld or puddle will be developed.

**Bronze Welding.** The advantages of bronze welding, or "welding with bronze" are numerous. Because of the low temperatures required, the speed of welding is increased, there is less warpage, less gas consumption, less preheating necessary, and less heat damage to the welded parts. Since bronze welding utilizes less preheating, the problem of expansion and contraction are greatly reduced. See Fig. 14.

Unlike metals, such as steel to cast iron, or alloy steels to steel can be bronze welded very readily. If properly done bronze welding can be depended upon to give
Bronze Welding

Fig. 14
a strong, tight joint of about twice the strength of cast iron. When building up broken or worn shafts this metal proves to be very desirable. It is easily machined, and does not distort the shafts while being welded.

Bronze welding may be applied with success on steel, steel alloys, cast iron, and copper. It differs from other types of welding in that it does not fuse with the base metal, it only adheres. This adhesion is simplified by the use of a designed welding flux, called "borax." The welding process uses bronze welding rod to supply the weld metal while the oxyacetylene flame provides the heat to complete the operation.

**Bronze Welding Steel.** The application of brass or bronze to steel requires technique and careful preparation. Surfaces should be cleaned by grinding, filing, sanding, sand blasting, or chipping. Butt joints that are large should be properly veeed to provide good bonding surface.

Bronze welding requires a slightly oxidizing flame. The flame is adjusted to a neutral flame, then the oxygen valve is adjusted to decrease the size of the neutral cone just slightly.

The joint should be preheated to a dull red for a short distance. If the bronze is applied at the correct temperature, it will flow like water and adhere to the
metal securely. However, if the metal is too cold it will not receive the molten bronze. If too high a temperature is used the bronze will form into small balls and be driven off the metal by the force of the flame.

Tinning the surface by applying a small amount of well fluxed rod to the heated area is of utmost importance. If at all possible, after the tinning process, the weld should be built up in one pass. A slight zigzag motion of the torch will produce a smooth appearing ripple.

**Bronze Welding Cast Iron.** In many ways, bronze welding cast iron is accomplished similar to that of steel. The cast iron metal must be properly cleaned and veeed before welding.

A special cast iron flux should be employed and the surface well tinned, as on steel. Cast iron bronze welding has narrower temperature limits than steel: Therefore, it is gradually heated and occasionally the flux coated rod may be touched to the welded area as it reaches the red heat. All sides of the vee should be thoroughly tinned and then filled for proper reinforcement. Bronze welding cast iron is also classified as an adhesion process. However, since cast iron grain structure differs from that of steel, there is a certain amount of intergranular penetration.

**Cutting With Torch.** The cutting torch is a mechanical device which uses the principle that red hot metal
oxides more rapidly than when cold. By localizing the heat and having the oxygen under pressure, rapid oxidation takes place when the heat and oxygen are directed on the metal. As the torch is moved at the correct speed a small cut or kerf is made in the metal. The cutting attachment connects on the torch body by the same method as the tip, but it differs from the tip in construction and operation. Instead of one passage to the orifice, as in the tip, it has two. One carries the mixing gases for the preheating flame and the other carries oxygen under high pressure which can be turned on and off by a trigger valve. It also has another valve for the preheating flame. The tip is made of copper and instead of having one orifice it has a number of them, usually five. The center orifice is the largest and has four smaller ones spaced equally around it. These small orifices are used for the preheating flame and the larger for the cutting oxygen. See Fig. 15.

The cutting attachment is first attached to the torch body. The acetylene pressure is set to approximately 5 lbs. the oxygen to about 25 lbs. The oxygen needle valve on the handle is opened all the way while the acetylene valve is opened slightly and the flame is ignited. The oxygen needle valve on the attachment is opened until the flame is adjusted to a neutral flame, then the cutting oxygen lever is depressed and the flame is readjusted to a neutral one.
Cutting Torch

Fig. 15
This is the procedure, with the cutting valve closed apply the heating flames to the edge of the metal, keeping the nozzle at such a distance that the small flames barely touch the metal. As soon as the metal becomes heated to a cherry red, open the cutting valve, raise the torch slightly to increase the distance between the nozzle and the metal, and then move your torch along the surface as fast as a distinct and clear kerf can be secured. The torch should be held at a constant distance from the work, and should travel away from the operator in order that he may watch the cut in advance.

Steel and wrought iron are the only metals that can be cut successfully by means of the oxygen jet.

This phase of the thesis revealed the instructions for welding technique, bronze welding of steel and iron, and cutting of ferrous metals.

The next page takes the reader to the initial work sheet in the series of thirty-two, all of which follow and comprise the manual.
Work Sheets and Drawings
SETTING UP EQUIPMENT

Objective: To teach the set up of the welding outfit.

Tools and Equipment:
1. Proper wrenches
2. One full acetylene cylinder
3. One full oxygen cylinder
4. One oxygen and acetylene pressure regulator
5. One twin hose complete with fittings
6. Torch body and tip
7. Acetylene regulator adapter if needed
8. Cylinder truck

Procedure:
1. Place cylinders on truck and secure
2. Remove cylinder valve caps
3. Place wrench on acetylene cylinder
4. Crack cylinder valves quickly
5. Clean all fittings if necessary
6. Attach regulators
7. Attach hose line
8. Blow out regulators and hose
9. Attach torch body to hose
10. Blow out torch body
11. Attach tip
12. Check fittings for leaks
Work Sheet 2

LIGHTING AND ADJUSTING TORCH

Objective: To teach the proper procedure in lighting and adjusting the torch.

Tools and Equipment:
1. Welding outfit completely set up.
2. Sparklighter.

Procedure:
1. Release regulator adjusting screws.
2. Open acetylene cylinder valve 1/4 to 1/2 turn.
3. Leave wrench in place on valve.
4. Open oxygen cylinder valve completely.
5. Adjust acetylene regulator to working pressure.
6. Adjust oxygen regulator to working pressure.
7. Open acetylene torch valve 1/4 turn.
8. Open oxygen torch valve slightly.
10. Open acetylene and oxygen torch valves until a neutral flame is reached.
11. To shut off torch close acetylene valve first and then close the oxygen valve.
Work Sheet 3

EDGE FUSING

Objective: Teaching how to form and maintain puddle.

Tools and Equipment:
1. Welding bench
2. Welding outfit
3. Tool kit

Material:
1. Two pieces of .065" x 1" x 5" mild steel.

Procedure:
1. True up surfaces of stock to get proper fit.
2. Select and insert proper welding tip into torch body.
3. Adjust acetylene working pressure.
4. Adjust oxygen working pressure.
5. Light torch and adjust to neutral flame.
6. Hold two pieces of metal together with C clamp, and tack both ends of top side.
7. Place stock between two bricks and leave edge to be welded projecting above brick surface.
8. Start puddle formation at right hand corner. See Fig. 16.
9. Move torch toward left as puddle forms in a slight zigzag path.
10. Repeat same operation around stock until all edges have been fused together.
12. Check work with instructor.
Edge Fusing

Fig. 16
RUNNING BEADS WITHOUT ROD

Objective: Teach method of running beads across a flat surface to meet given specifications.

Tools and Equipment:
1. Welding bench
2. Welding outfit
3. Tool kit

Material:
1. One piece of .065" x 6" mild steel.

Procedure:
1. Draw guide lines across stock 1/2" apart, See Fig. 17.
2. Prick punch guide lines every 1/2".
3. Place stock flatly across two bricks leaving space between the bricks in preparation for welding.
4. Set up torch using proper tip and a neutral flame.
5. Start puddle on right hand edge and then go to left.
6. Use guide line to form center of bead.
7. Carry bead across plate along guide line. See Fig. 17.
8. Width of bead should be four times the thickness.
9. Repeat same operation on each guide line.
10. Secure torch.
11. Check work with instructor.
Running Beads Without Rod

Fig. 17
Work Sheet 5

RUNNING BEADS WITH ROD

Objective: To teach the method of adding filler rod to molten puddle while running beads.
To form beads according to given specifications.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. One piece of 3/32" x 6" x 6" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Lay out guide lines on stock.
2. Set up stock for welding.
3. Set up torch using proper tip and a neutral flame.
4. Begin weld by forming puddle.
5. After puddle is formed add rod with left hand at required intervals and at the same time move torch in a slight zigzag path, see Fig. 18.
6. Width of bead should be four times the thickness and the reinforcement should be around 25 per cent.
7. Run similar beads on all guide lines.
8. Secure torch.
9. Check work with instructor.
Running Beads With Rod

Fig. 18
Objective: Teach how to make outside corner welds and how to control rod and puddle.

Tools and Equipment:
1. Complete welding outfit.
2. Tool kit.

Material:
1. Two pieces of .065" x 1" x 6" mild steel.
2. Welding rod, 1/16"-mild steel.

Procedure:
1. Set metal strips at 90 degree angle on bricks of table.
2. Light torch and adjust to neutral flame.
3. Tack weld plates at the ends and at the required angle.
4. See Fig. 19.
5. Weld full length allowing full penetration.
6. Reinforcement about 25 per cent
7. Secure torch.
8. Check work with instructor.
Outside Corner Weld With Rod

Fig. 19
Objective: To teach the effect of the three different types of flames upon metal.

Tools and Equipment:
1. Complete welding outfit set up as for preceding job.

Material:
1. Six pieces .065" x 1" x 3" mild steel.
2. Welding rod 1/16" mild steel.

Procedure:
1. Set up two pieces of metal stock at 90 degree angle on bricks of table.
2. Adjust torch for an oxidizing flame and weld the two pieces of stock, being careful not to allow your flame to creep. Weld the entire length of stock, see Fig. 20.
3. With two other pieces of stock, repeat the above operations, using a carbonizing flame.
4. With the two remaining pieces of stock, repeat the above operations, using neutral flame.
5. Compare the three welds which have been completed and look for: (a) pitted and burned surfaces on oxidized weld, (b) fan shaped rays effect on carbonized weld, and, (c) smooth bead on neutral weld.
6. Place the three pieces in a vise and break the welded areas and compare the properties.
90 DEGREE OUTSIDE CORNER WELDS

Fig. 20
Objective: Teaching procedure of making butt weld.

Tools and Equipment:
1. Complete welding outfit.
2. Tool kit.

Material:
1. Two pieces 3/32" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. With space between, place pieces together on fire brick.
2. Select proper tip, attach, light and adjust flame.
3. Tack both ends, leaving 1/16" between pieces.
4. Use forehand technique, see Fig. 21.
5. Secure torch.
6. Check work with instructor.
Butt Weld

Fig. 21
Objective: Teach the proper procedure for making a butt weld to given specifications.

Tools and Equipment:
1. Complete welding outfit.
2. Tool Kit.

Material:
1. Two pieces of .065" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. With space between bricks, place pieces on fire bricks.
2. Space the pieces one-half the thickness of stock.
3. Tack weld at four equal spaces, starting from one end.
4. Weld full length to following specifications:
   (a) penetration complete, (b) reinforcement 25 per cent, and, (c) width of bead four time the thickness, see Fig. 22.
5. Secure torch.
6. Check work with instructor.
Butt Weld With Specifications

Fig. 22
Objective: Teach the procedure in making a 45 degree angle weld.

Tools and Equipment:
1. Complete welding outfit.
2. Tool kit.

Material:
1. Two pieces of .065" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Set up torch using proper tip.
2. Tack weld at four equal spaces.
3. Set spare fire brick on bench, see Fig. 23.
4. Start weld at bottom and weld up.
5. Secure torch.
6. Check work with instructor.
45 Degree Angle Butt Weld

Fig. 23
Objective: Teach the proper procedure in making a vertical butt weld.

Tools and Equipment:
1. Complete welding outfit.
2. Tool kit.

Material:
1. Two pieces of .065" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Set up torch using proper tip.
2. Tack weld at four equal spaces.
3. Clamp stock at desired level in a vertical position.
4. Weld from bottom up, see Fig. 24.
5. Secure torch.
6. Check work with instructor.
Butt Weld, Vertical

Angle of torch in relation to rod and base metal

Fig. 24
Work Sheet 12

BUTT WELD, BACKHAND

Objective: Teach the proper position and procedure in making a butt weld using backhand method.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit.

Material:
1. Two pieces of .065" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Space and tack as in previous butt welds.
2. Place in a flat position over two bricks and allow space between the bricks.
3. Weld with flame ahead of the rod, see Fig. 25.
4. Direct flame slightly ahead of rod and puddle.
5. Preheat ahead of puddle.
7. Check work with instructor.
Butt Weld, Backhand

Fig. 25
Work Sheet 13

BUTT WELD, OVERHEAD

Objective: Teach the proper method of making a butt weld in an overhead position.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces of .065" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Tack weld at four equal spaces.
2. Provide an upright angle iron or bar and clamp stock in an overhead position.
3. Adjust to proper height.
4. Weld with the forehand method, rod ahead of flame, see Fig. 26.
5. Secure torch.
6. Check work with instructor.
Butt Weld, Overhead
Work Sheet 14

SAW TOOTH BUTT WELD

Objective: Familiarize students how to make saw tooth butt welds in different directions.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces of .065" x 2" x 4" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Layout plates as shown in Fig. 27.
2. Cut with hack saw and file for proper fit.
3. Allow one half thickness of plate for space between butt.
4. Tack weld both ends and all tooth points.
5. Commence welds from center out, see drawing.
6. Avoid burning tooth ends.
7. Secure torch.
8. Check work with instructor.
Saw Tooth Butt Weld

Fig. 27
Work Sheet 15

LAP WELD, FLAT POSITION

Objective: Teach the proper procedure in making a lap weld in a flat position with 1/16" material.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces of .065" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Lap plate No. 1, 3/8" over plate No. 2, see Fig. 28.
2. Tack weld at four equal spaces.
3. Preheat both plates, direct flame at plate No. 2, add rod at the right edge of plate No. 1.
4. Bead should appear convex.
5. Penetration should overlap the corners.
7. Check work with instructor.
Lap Weld, Flat Position

Fig. 28
Work Sheet 16

LAP WELD, FLAT POSITION

Objective: Teach the proper procedure in making a lap weld in a flat position with 1/8" material.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces .125" x 1-1/4" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Lap plate No. 1, 3/8" over plate No. 2, see Fig. 29.
2. Tack weld at four equal spaces.
3. Preheat both plates, direct flame at plate No. 2, add rod at the edge of plate No. 1.
4. Bead should appear convex.
5. Penetration should overlap the corners.
7. Check work with instructor.
Lap Weld, Flat Position
Worksheet 17

LAP WELD, VERTICAL UP

Objective: Teach the proper procedure in making a vertical lap weld up.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces of .065" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Lap one plate approximately 3/8" over the other.
2. Tack weld at four equal spaces.
3. Clamp the tacked stock to the weld position.
4. Adjust height for individual need.
5. Weld using forehand technique from bottom up, see Fig. 30.
7. Check work with instructor.
Lap Weld, Vertical Up

Fig. 30
Work Sheet 18

LAP WELD, VERTICAL DOWN

Objective: Teach the proper procedure in making a vertical lap weld down.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces of .065″ x 1-1/4″ x 5″ mild steel.
2. Welding rod, 1/16″ mild steel.

Procedure:
1. Lap one plate approximately 3/8″ over the other.
2. Tack weld at four equal spaces.
3. Clamp the tacked stock to the weld positioner.
4. Weld using back hard technique from top down, see Fig. 31.
5. Direct flame up into the bead.
6. Rod is to follow the flame.
7. Add rod closely to flame, solidification will be avoided.
8. Secure torch.
9. Check work with instructor.
Lap Weld, Vertical Down

Fig. 31
Work Sheet 19

LAP WELD, OVERHEAD

Objective: Teach the proper procedure in making a lap weld overhead.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces .065" x 1-1/4" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Lap one plate approximately 3/8" over the other.
2. Tack weld at four equal spaces.
3. Clamp the tacked stock to the weld positioner.
4. Adjust to individual eye level.
5. Weld full length using the forehand technique overhead, see Fig. 32.
6. Direct flame up into bead.
7. Avoid adding too much rod as it will drop down when molten.
8. Rod is to be ahead of the flame.
10. Check work with instructor.
Lap Weld, Overhead

Fig. 32
Objective: Teach the proper procedure in making a tee weld flat.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces .125" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Tack plates at both ends at a 90 degree angle to form a T as shown in Fig. 33.
2. For support add two more tacks equally spaced.
3. Place on bricks horizontally with space between bricks.
4. Weld full length using forehand technique.
5. Penetrate weld at least fifty per cent of thickness of plate.
6. Width of bead to be four times the thickness of plate.
7. Reinforcement should be about once times the thickness of plate through throat, see Fig. 33.
8. Secure torch.
9. Check work with instructor.
Tee Weld, Flat

Fig. 33
Objective: Teach the proper procedure in making a vertical tee weld down.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces .125" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Tack plates at both ends at a 90 degree angle to form a T as shown in Fig. 34.
2. Add two more tacks equally spaced.
3. Place on bricks vertically.
4. Weld full length from top to bottom using backhand technique.
5. Penetrate weld at least fifty per cent of thickness of plate.
6. Width of bead to be four times the thickness of plate.
7. Reinforcement should be about once times the thickness of plate.
8. Secure torch.
9. Check work with instructor.
Tee Weld, Vertical Down

Fig. 34
45 DEGREE, RESTRICTED ANGLE

Objective: Teach the proper procedure in making a 45 degree restricted angle weld.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces .125" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Tack plates at both ends at a 45 degree angle as shown in Fig. 35.
2. Add two more tacks equally spaced.
3. Place tacked plates on two bricks with a space between the bricks.
4. Weld full length using forehand technique.
5. Penetrate completely to bottom of angle.
6. The thickness of bead should be twice times the thickness minimum.
7. Secure torch.
8. Check work with instructor.
45 Degree, Restricted Angle

Fig. 35
Objective: Teach the proper procedure in making a 60 degree restricted angle weld.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces .065" x 1" x 5" mild steel.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Tack at four places equally spaced at 60 degree angle, see Fig. 36.
2. Place tacked plates on two bricks with a space between the fire bricks.
3. Weld full length using forehand technique.
4. Penetrate completely to bottom of angle.
5. Thickness of bead should be twice times the thickness.
7. Check work with instructor.
60 Degree, Restricted Angle

Fig. 36
Work Sheet 24

STEEL TUBING, BUTT WELD

Objective: Teach proper method in making butt welds on steel tubing.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces of steel tubing .065" x 1" diameter x 1-1/2" long.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Place on brick in a horizontal position and tack weld in four equally spaced distances, allow 1/32" gap.
2. Begin the weld on the side and move towards top, see Fig. 37.
3. Turn the tube as weld progresses.
4. End of weld must overlap the beginning of weld by the width of the bead.
5. Penetration should be full.
6. Reinforcement to be 25 per cent.
7. Width of bead four times the thickness.
8. Secure torch
9. Check work with instructor.
Steel Tubing, Butt Weld

Fig. 37
Work Sheet 25

STEEL TUBING, BUTT WELD HORIZONTAL FIXED

Objective: Teach the proper method in making a butt weld on steel tubing in a horizontal fixed position.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces steel tubing .065" x 1" diameter x 1-1/2" long.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Place on brick in a horizontal position and tack weld in four equally spaced distances, allow 1/32" gap.
2. Set up tubing in a horizontal position at a comfortable working height.
3. Start at bottom of weld joint and weld half way around to the top of the joint, see Fig. 38.
4. Return to the bottom of joint and weld remaining half of joint and overlap the endings equal to the width of bead.
5. Penetration one half of metal thickness a minimum.
6. Reinforcement two times the thickness a minimum.
7. Width of bead four times the thickness.
8. Secure torch.
9. Check work with instructor.
Steel Tubing, Butt Weld Horizontal Fixed

Fig. 38
Objective: Teach proper method of making a tubing butt weld in a vertical fixed position, teach quarter weld method.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces of mild steel tubing .065" x 1" diameter x 1-1/2" long.
2. Welding rod, 1/16" mild steel.

Procedure:
1. Place on brick in a horizontal position and tack weld in four equally spaced distances, allow 1/32" gap, see Fig. 39.
2. Set up and mount the tubing in a vertical fixed position at approximately eye level.
3. Start at point D (shown in drawing) and run bead to C.
4. Begin second bead at point D and run bead to A.
5. Begin third bead at point D and run to A.
6. Finish the weld by running a bead from point B to C.
7. Secure torch.
8. Check work with instructor.
Steel Tubing, Butt Weld Vertical Fixed

Fig. 39
Work Sheet 27

STEEL TUBING, FILLET WELD

Objective: To teach the proper method of making a fillet weld on a tube attached to a plate.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. One piece of tubing .065" x 1" diameter x 1-1/2" long.
2. One plate 2" x 2" x .065".
3. Welding rod, 1/16" mild steel.

Procedure:
1. Tack tubing to plate at four equal spaces at a 90 degree angle as shown in Fig. 40.
2. Place tacked tube and plate on top of two bricks allowing some space between the bricks.
4. Check work with instructor.
5. Saw in half, place in vise, file surfaces, smooth down with fine emery cloth, and then etch with a solution of aqueous hydrochloric acid.
6. Examine with magnifying glass.
7. Penetration to be one half the metal thickness.
8. Reinforcement twice the thickness.
10. Check work with instructor.
Steel Tubing, Fillet Weld

Fig. 40
Work Sheet 28

STEEL TUBING, TEE WELD

Objective: Teach the proper procedure in fitting and welding steel tubing at a 90 degree angle.

Tools and Equipment:
1. One piece of tubing .065" x 1-1/8" diameter x 3" long.
2. One piece of tubing .065" x 7/8" diameter x 1-1/2" long.
3. Welding rod, 1/16" mild steel.

Procedure:
1. Fit 7/8" tube to 1-1/8" tube at a 90 degree, see Fig. 41.
2. On each side tack tube (A) to tube (B)
3. Allow no space between the tubes.
4. Weld in quarters from restricted angle out, see Fig. 41.
5. End all welds on both sides at same place.
7. Check work with instructor.
Steel Tubing, Tee Weld

Fig. 41
Objective: Teach the proper procedure in making a butt braze.

Tools and Equipment:
1. Complete welding outfit
2. Tool kit

Material:
1. Two pieces of .125" x 1" x 5" long mild steel.
2. Brazing rod, 3/32".
3. Brazing flux, as required.

Procedure:
1. Place pieces on fire brick and allow a 1/16" gap between the pieces.
2. Tack both ends first and then in three other places tack again equally spaced, see Fig. 42.
3. Heat end of rod and dip into brazing flux.
4. Heat area to be brazed to a dull red color.
5. Commence welding using the forehand technique.
6. Weld full length and observe proper tinning during the process.
7. Penetrate completely.
8. Bead should be smooth.
10. Check work with instructor.
Butt Weld, Braze

Fig. 42
Work Sheet  30

LAP WEID, BRAZE

Objective: Teach the proper procedure in making a lap weld braze.

Tools and Equipment:
1. Complete welding outfit.
2. Tool kit.

Material:
1. Two pieces .125" x 1" x 5" long mild steel.
2. Brazing rod, 3/32".
3. Brazing flux, as required.

Procedure:
1. Place pieces on fire brick, allow space between bricks.
2. Lap 3/8", tack both ends first and then tack in three other places equally spaced, see Fit. 43.
3. Heat end of rod and dip into brazing flux.
4. Heat the metal until the bronze will flow smoothly.
5. Commence welding using forehand technique.
6. Weld full length and observe proper tinning during process.
7. Penetrate under the lap area.
8. Reinforcement about 25 per cent.
10. Check work with instructor.
Lap Weld, Brazing
Work Sheet 31

OXYACETYLENE CUTTING OF MILD STEEL

Objective: Teach students how to cut with an oxyacetylene cutting torch.

Tools and Equipment:
1. Complete oxyacetylene cutting outfit.
2. Cutting tips, cutting attachment.
3. Tool kit.
4. Straight edge for guiding cutting torch.
5. Grinder of any make.

Material:
1. 1/4" x approximately 5" x 8" long mild steel.

Procedure:
1. Lay out stock as shown in Fig. 44, allow 1/8" for kerf.
2. Lay out straight edge on stock so that the central orifice of cutting tip when held against the straight edge is directly above the line to be cut.
3. Adjust pressures, oxygen approximately 30 lbs., acetylene approximately 5 lbs., and light torch.
4. Have instructor check pressures.
5. Adjust torch to a neutral flame with cutting oxygen lever depressed.
6. Preheat edge of metal at the end of the line with the neutral flame.
7. Cut should progress in a direction that will prevent the bulk of the torch and the hoses from passing over the heated area or metal.
8. Start the cut away from you and work toward yourself and the head and tip of the torch will not obscure the line to be cut.
9. When edge of metal on the line to be cut reaches a dull red depress the cutting oxygen lever and move torch steadily along the line of cut until the end of the line is reached.
10. Preheating flames of the torch should be held about 1/16" off the work during the operation.
11. Cut should progress as fast as possible.
12. When the cut is finished remove torch from work and release the cutting oxygen lever.
13. Proceed with all cuts until the job is completed.
14. After metal has cooled in air, chip or grind slag of the metal.
15. Check working dimensions for accuracy.
17. Check work with instructor.
Oxyacetylene Cutting of Mild Steel
Objective: Teach the proper procedure while welding heavy metal.

Testing of progress in welding.

Tools and Equipment:
1. Complete welding and cutting outfit.
2. Tool kit.

Material:
1. Two pieces of steel plate, 1/4" x 3-7/8" x 4-3/8".
2. Welding rod, 3/32".

Procedure:
1. Bevel edges to be welded to a 45 degree angle, see Fig. 45.
2. Leave 3/32" at the bottom of the edges.
3. Set up metal to be welded on two bricks allowing some space between the bricks.
4. Allow a 3/32" gap between the two metal pieces and tack in four equal spaces.
5. Select proper tip, attach, light, and adjust to neutral flame.
6. Use forehand technique while welding.
7. Make the weld in one pass.
8. Penetration should be complete.
9. Reinforcement about 25 per cent.
10. Mark and cut out with cutting torch as shown in Fig. 45 and Fig. 46.
11. Test all welds in a tensile machine, see instructor.
12. Secure welding and cutting torches.
13. Check work with instructor.
1/4 Inch Test Butt Weld

Fig. 1

Fig. 45

Fig. II

Fig. 46
Chapter VII

SUMMARY, CONCLUSIONS, AND FURTHER STUDIES SUGGESTED

The primary purpose of this study was to discover, organize, and present material on oxyacetylene welding and cutting and show how the study of oxyacetylene welding could be developed into a manual as part of an industrial arts program. The study reveals:

1. Oxyacetylene welding is a non-pressure process of joining two pieces of metal by fusing their adjacent edges with a flame of which acetylene and oxygen are the constituents. Oxyacetylene welding has many industrial applications.

2. The names of early personalities and the respective discoveries associated with their names. Acetylene is made from calcium carbide while commercial oxygen is made from the air by the liquid air process. The welding and cutting torches are the physical mechanisms for the mixing of the gases and the necessary means for the control of the flame. Oxyacetylene welding is a non-pressure process wherein the heat is obtained from an oxyacetylene flame, formed by the combustion of equal amount of oxygen and acetylene. Oxyacetylene cutting is the process of preheating the metal to be cut to its kindling or ignition
temperature and then rapidly oxidizing it by means of a closely directed stream of oxygen.

3. The related information and description of each part in terms of design and function.

4. Specific instructions for organization and operation of welding and cutting with reference to the various flames, their descriptions and the flame adjustment illustration.

5. A list of safe precautions in relation to organization and operation of an oxyacetylene unit which involves handling, storage and use of cylinders.

6. Instructions for welding, bronze welding, bronze welding of steel and iron, and for cutting procedure; also, the series of work sheet drawings which are a part of the manual.

Conclusions

1. The development of the oxyacetylene process displaced the blacksmith to a large extent and has shown tremendous progress and wide industrial applications in its short period of inception. The development is associated principally with the twentieth century.

2. Education on the secondary level can be enriched by the study of oxyacetylene welding in the industrial arts laboratory.
3. This thesis is evidence that there is much technical material available which has to be interpreted and rewritten for high school adoption.

4. The thesis provides sufficient material for a possible manual of instruction for industrial arts teaching.

5. This study is necessarily incomplete and is offered for orientation purposes.

6. It is hoped that industrial arts teachers will be challenged to use this material for possible study and resultant use.

**Further Studies Suggested.** A study which terminates in an atmosphere of continued thought and its interpretation to other fields and application is considered to be of potential value. This study can possibly reveal other studies and investigations as suggested in the following.

- Oxyacetylene Welding in a Rural High School
- Resistance Welding in the Industrial Arts Program
- Welding and Its Application to Structural Steel
- Oxyacetylene Welding in a Transportation Area
- Aircraft Welding
- Welding and Its Use in Heat Treatment of Steel
Welding of Aluminum as Content for Industrial Arts
Welding in the Ship Building Industry
Sheet Metal Welding
The Brazing Phase of Welding
Welding as a Private Enterprise
Welding in the Railroad Industry
Arc Welding in the Industrial Arts Laboratory
Welding in the Petroleum Industry
BIBLIOGRAPHY


9. Cummings, W. C. *Course Outline in Metallography for Welders*, Nebraska, Department of Vocational Education.


31. Ohio School Standards, 1937, Revision


47. Warner, William E. "How Do Interpret Industrial Arts?" Industrial Arts and Vocational Education, February 1936.


APPENDICES
SLIDE FILMS AND SOUND FILMS

Slide films and 16 mm. movie films can be of great value to instructors of oxyacetylene welding. These may be obtained from the "Jam Handy Organization, 2821 East Grand Blvd., Detroit, Michigan.

1. Introduction to Welding
2. Setting Up and Lighting of Welding Torch
3. Welding Flat Ripples
4. Flat Butt Weld
5. Fillet Welds - Steel
6. Vertical Welds
7. Tubing Welds
8. Oxy-Acetylene
9. Welding Stainless Steel
10. Brazing and Silver Soldering
11. Welding Aluminum - Flat Sheets
12. Welding Aluminum - Tubing
13. Qualification Tests for Welders
MELTING POINTS OF METALS AND ALLOYS

In welding it is necessary to have metal of different alloys heated until they become molten or plastic. Because of the great difference in the melting point of different alloys, it is of great importance that every man attempting to weld should have a general knowledge of the melting point of different metals and their alloys.

Below is listed the melting point of several basic metals and their alloys. Notice that a variation in the composition of an alloy increases or decreases the melting point of these alloys.

<table>
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<th>Metal and Alloys</th>
<th>Melting Point (degree F.)</th>
<th>Metal and Alloys</th>
<th>Melting Point (degree F.)</th>
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<td>Aluminum</td>
<td>1215</td>
<td>Tin</td>
<td>450</td>
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<tr>
<td>Aluminum alloys</td>
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<td>Zinc</td>
<td>786</td>
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<td>Silver</td>
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<td>1981</td>
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<td>Nickel</td>
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<td>Steel 1015</td>
<td>2705</td>
<td>Vanadium</td>
<td>3180</td>
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<td>Solder 60-40</td>
<td>365</td>
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<td>----</td>
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</tr>
<tr>
<td>Width of bead 4xT</td>
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<td>Depth of penetration - Full</td>
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<td>Finish of ends of weld</td>
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<td><strong>TOTAL</strong></td>
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Student's Name ___________________________    Date ____________

Student Instructor _______________________
### Tip Sizes and Approximate Gas Pressures

#### For Cutting

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#### For Welding

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<td>1.3</td>
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GLOSSARY
 TERMS USED IN OXYACETYLENE WELDING AND CUTTING INSTRUCTION COURSE

ACETONE ........ Is used as the solvent liquid in acetylene cylinders.

ACETYLENE ...... A combustible gas of high thermal value produced by calcium carbide and water, and used for welding and cutting.

ADAPTOR ........ A part used to connect to another part that is of a different size or thread.

ADDING MATERIAL. Also called welding rod. The filler rod used in welding where the metals to be joined exceed a certain thickness.

ADHESION ........ A condition in a weld which results from imperfect amalgamation.

ALIGNMENT ...... Setting up broken pieces as near to their original shape as is possible.

ATMOSPHERE ..... The pressure of the air at sea level 14.7 pounds per square inch.

BACKFIRE ........ This is indicated in the torch by a snap or pop. Flames leaving the torch tip but immediately relighting itself.

BACKHAND WELDING A technique of welding where flame is directed back against the completed weld.

BACKING STRIP .. A piece of material used to retain molten metal at the root of the weld.

BASE METAL ..... Materials composing the pieces to be united by welding. Also called parent metal.

BEAD ............. Metal deposited in welding in a single direction.

BEVEL ............. An edge of metal cut at an angle.

BLOW HOLE ...... A hole or cavity formed by trapped gases, dirt, grease or other foreign matter. Usually caused by welding too fast.
BUTT WELD ...... A weld in which two plates or surfaces are brought together edge to edge and welded.

CARBURIZING ...... A flame in which there is an excess of acetylene.

COMBUSTION ...... The process of oxidation or burning.

CONE ............ That part of the welding flame that is conical in shape at end of torch tip.

CREEPING ........ The low pressure gauge of regulator sometimes builds up a pressure when not in use. In such cases the seat of the regulator should be examined.

DUCTILITY ........ Property possessed by metals that allows them to be drawn or stretched.

EDGE WELD ....... Joining of two parallel pieces by welding edges together.

ELONGATION ...... The stretch of metal when pulled in a testing machine.

EXPANSION ........ The increase in the dimensions of metals due to heat.

FLASHBACK ....... A flashback occurs when the flame disappears from the end of tip and the gases burn within the torch.

FLUX ............. A cleansing agent used to dissolve oxides, release trapped gases and slag and to cleanse metals for welding, soldering and brazing.

FOREHAND WELDING. The technique employed in welding in which the flame is directed against the base metal ahead of the completed weld.

FUSION WELD ...... A weld formed by heating to a fluid state the edges of the pieces to be joined, allowing the metal to flow together without using pressure.

FILLET WELD ...... Is one in which some fixture or member is welded to the face of a plate by welding along the vertical edge of the fixture.
LAP WELD ...... Where the edges of two plates are set one above the other so edge of one plate can be welded to the face of the other plate.

LIQUEFACTION ... Reduction of gas to a liquid state by compression and refrigeration.

NON-FERROUS .... Metals containing no ferrite or iron. Non-ferrous metals used are copper, brass, bronze, aluminum and lead.

OXIDE ............ A term usually applied to rust, erosion, coating, film or scale.

OXIDIZING FLAME. Unbalanced combustion caused by using an excess of oxygen.

PEENING .......... Stretching the surface of cold metal by hammering.

PENETRATION ....... Starting complete fusion of sides of weld clear through from the bottom up.

WELD METAL ....... Material which has been used in forming a weld.