МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ЧЕРНІГІВСЬКИЙ НАЦІОНАЛЬНИЙ ТЕХНОЛОГІЧНИЙ
УНІВЕРСИТЕТ

АНГЛІЙСЬКА МОВА У ЗВАРЮВАЛЬНОМУ ВИРОБНИЦТВІ

МЕТОДИЧНІ ВКАЗІВКИ
до практичних занять
для студентів денної форми навчання
напряму підготовки 131 “Технології та устаткування зварювання ”

Обговорено і рекомендовано
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Англійська мова у зварювальному виробництві. Методичні вказівки до практичних занять для студентів денної форми навчання напряму підготовки 131 «Технології та устаткування зварювання» / Укл. Сікалюк А.І., Пермінова В.А. – Чернігів: ЧНТУ, 2017. − 56 с.

Укладачі:	СІКАЛЮК АНЖЕЛА ІВАНІВНА, кандидат педагогічних наук, старший викладач кафедри іноземних мов професійного спрямування; ПЕРМІНОВА ВЛАДИСЛАВА АНАТОЛІЇВНА, кандидат педагогічних наук, старший викладач кафедри іноземних мов професійного спрямування
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Зміст

Передмова

Методичні вказівки «Англійська мова у зварювальному виробництві» складені у відповідності до вимог Програми викладання англійської мови професійного спілкування (Київ, 2005) та призначені для студентів денної форми навчання напряму підготовки 131 “Технології та устаткування зварювання” немовних вузів, які продовжують вивчення англійської мови на базі знань, отриманих в середній школі. Головна мета методичних вказівок – розвиток умінь розуміння й аналізу текстів, накопичення словникового запасу, уміння вести бесіду, брати участь у дискусіях англійською мовою, формувати позицію фахівця іноземною мовою в галузі зварювального виробництва.

Методичні вказівки включають три основних розділи, які містять неадаптовані професійно-орієнтовані тексти, комплекс комунікативно-спрямованих завдань, які сприятимуть кращому оволодінню англійською мовою професійного спрямування, розвитку комунікативних навичок, а також вирішенню професійних завдань засобами іноземної мови.

Методичні вказівки доповнено тлумачним термінологічним словником для фахівців у галузі зварювального виробництва, який представлений у додатку А.

1 JOB DESCRIPTION AND WELDING EDUCATION

1.1 Lead-in

In the list below tick the places where welders are not likely to work. Add some more places to the list.

- machine-building factory workshop;
- bridge construction site;
- hospital;
- university department;
- shipyard;
- bank;
- repair shop;
- assembly site;
- bakery.

1.2 Reading

Find the Ukrainian equivalents for the words and word combinations in italics in the text.

Welding & Machine Trades

Welding is a skill used by many trades: **sheet metal workers**, **ironworker**s, diesel mechanics, boilermakers, **carpenters**, marine construction, steamfitters, **glaziers**, **repair and maintenance** personnel in applications ranging from the home **hobbyist** to heavy fabrication of bridges, ships and many other projects. A variety of welding processes are used to *join units of metal*. As a welder, you may work for shipyards, manufacturers, **contractors,** federal, state, county, and city governments, firms requiring *maintenance mechanics*, and **repair shops**.

Welding, while very physically demanding, can be very rewarding for those who enjoy working with their hands. Welders need *good eyesight*, *manual dexterity* and *hand-eye coordination*. They should also be able to concentrate for long periods of time on very detailed work, as well as be in good enough *physical shape* to bend and **stoop**, often holding awkward positions for long periods of time. Welders work in a variety of environments, both indoors and out, using heat to melt and fuse separate pieces of metal together. Training and skill levels can vary, with a few weeks of school or *on-the-job training* for the lowest level job and several years of school and experience for the more *skilled welding positions*.

Skilled welders often select and set up the welding equipment, execute the weld, and then examine the welds in order to make sure they meet the *appropriate specifications*. They may also be trained to work in a variety of materials, such as plastic, titanium or aluminum. Those with less training perform more *routine tasks*, such as the welds on jobs that have already been laid out, and are not able to work with as many different materials.

While the need for welders as a whole should continue to grow about as fast as average, according the U.S. Bureau of Labor Statistics, the demand for *low-skilled welders* should decrease dramatically, as many companies move towards *automation*. However, this will be partially balanced out by the fact that the demand for **machine setter**s, operators and **tenders** should increase. And more *skilled welders* on *construction projects* and equipment repair should not be affected, as most of these jobs cannot be easily automated. Because of the increased need for highly skilled welders, those with *formal training* will have a much better chance of getting the position they desire. For those considering to prepare themselves to a *meaningful welding-career*, there are many *options available*.

There are also different professional specialties and levels, that should be understood to make an informed choice. Some of these are: welder, welding machine operator, welding technician, welding schedule developer, welding procedure writer, testing laboratory technician, welding **non destructive testing** inspector, welding supervisor, welding instructor, welding engineer, procedure writer, testing laboratory technician, welding **non destructive testing** inspector, welding supervisor, welding instructor, welding engineer.

1.3 While-reading activity

Make a list of all the words in the text indicating:

a) welding professions and levels: welder, welding machine operator, …

b) trades where welding skill is used: …

c) places/fields a welder can work at (in): …

d) personal qualities a welder should have:

Answer the following questions on the text.

1. What are the trades where welding skills are used?
2. Where can welders work?
3. What personal characteristics should welders have?
4. How does the environment in which welders work vary?
5. What does it take to be s low-skilled/skilled welder?
6. What are welders able to do in terms of complexity of tasks and variety of materials?
7. What are the job opportunities for low-skilled/skilled welders for the nearest future as specified by the U.S. Bureau of Labor Statistics?
8. What are the advantages of having formal training for making a welding career?
9. As you see, welding includes various professional specialties and levels. What is yours?

Look through the last paragraph of the text and say, what exactly, in your opinion, the following welding specialists do:

welder	

welding machine operator
welding technician
welding schedule developer
welding procedure writer
testing laboratory technician welding non destructive testing inspector

1.4 Writing

Write five sentences (one per each paragraph) summarizing the main ideas of the text.

1.5 Reading

Skim the text to understand its main ideas

What is welding and what do welders do?

Welding is the most economical and efficient way to join metals permanently. It is the only way of joining two or more pieces of metal to make them act as a single piece. Welding is vital to our economy. It is often said that over 50% of the gross national product of the U.S.A. is related to welding in one way or another. Welding ranks high among industrial processes and involves more sciences and variables than those involved in any other industrial process. There are many ways to make a weld and many different kinds of welds. Some processes cause sparks and others do not even make them act as a single piece. Welding is vital to our economy. It is often said that over 50% of the gross national product of the U.S.A. is related to welding in one way or another. Welding ranks high among industrial processes and involves more sciences and variables than those involved in any other industrial process. There are many ways to make a weld and many different kinds of welds. Some processes cause sparks and others do not even require extra heat.

Welding can be done anywhere… outdoors or indoors, underwater and in outer space.

Nearly everything we use in our daily life is welded or made by equipment that is welded. Welders help build metal products from coffeepots to skyscrapers. They help build space vehicles and millions of other products ranging from oil drilling rigs to automobiles. In construction, welders are virtually rebuilding the world, extending subways, building bridges, and helping to improve the environment by building pollution control devices. The use of welding is practically unlimited. There is no lack of variety of the type of work that is done.

Welders are employed in many industry groups. Machinery manufacturers are responsible for agricultural, construction, and mining

machinery. They are also involved in bulldozers, cranes, material handling equipment, food-processing machinery, papermaking and printing equipment, textiles, and office machinery.

The fabricated metals products compiles another group including manufacturers of pressure vessels, heat exchangers, tanks, sheet metal, prefabricated metal buildings and architectural and ornamental work. Transportation is divided into two major groups: manufacturers of transportation equipment except motor vehicles; and motor vehicles and equipment. The first includes shipbuilding, aircraft, spacecraft, and railroads. The second includes automobiles, trucks, buses, trailers, and associated equipment.

A small group of welders belongs to the group of repair services. This includes maintenance and repair on automobiles or refers to the welding performed on industrial and electrical machinery to repair worn parts. The mining, oil extraction, and gas extraction industries form yet another group.

A large portion of the work involves drilling and extracting oil and gas or mining of ores, stone, sand and gravel.

Welders are also employed in the primary metals industries to include steel mills, iron and steel foundries, smelting and refining plants.

Much of this work is maintenance and repair of facilities and equipment. Another group is the electrical and electronic equipment companies. Welding done by this group runs from work on electric generators, battery chargers, to household appliances.

Public administration employs welders to perform maintenance welding that is done on utilities, bridges, government armories and bases, etc. Yet another group involves wholesale and retail establishments. These would include auto and agricultural equipment dealerships, metal service centers, and scrap yards.

Probably the smallest group of welders, but perhaps those with the biggest impact on the public are the artist and sculptors. The St. Louis Arch is possibly one of the best known. But there are many other fountains and sculptures in cities and neighborhoods around the world.

1.6 True or false?

1. Welding is an important process employed by modern industry.
2. All welding processes are similar.
3. All welding processes require work pieces to be heated.
4. The smallest group of welders belongs to the group of repair services.
5. Welding is the only way to join metals.

1.7 After-reading activity

Make up a summary of the text using the following sentences as a beginning:]

1. Welding is…. 2. Welding ranks… 3. There are many kinds… 4. Welding can be made… 5. Welders can… 6. The use of welding is… 7. Welders are employed in … .

1.8 Reading

Welding Skills

A Welder permanently joins pieces of metal with metal filler, using heat and/or pressure. Welders join parts being manufactured, they build structures and repair broken or cracked parts, according to specifications.

Job Related Skills, Interests and Values

- using and maintaining tools, material handling equipment and welding equipment;
- reading and interpreting **blueprints;**
- acquiring thorough knowledge of arc, gas and **resistance welding** theory ;
- laying out, cutting and forming metals to specifications;
- preparing the work site;
- fitting sub-assemblies and assemblies together and preparing assemblies for welding ;
- welding using **shielded metal arc welding**, gas metal arc welding, **gas tungsten arc welding**, flux core or metal core arc welding, submerged arc welding and plasma arc welding processes;
- carrying out special processes such as welding studs and brazing;
- ensuring quality of product/process before, during and after welding.

What Preparation and Training Do You Need?

To become a Welder you should complete Grade 12 with credits in mathematics (particularly technical math) and some shop courses. In Ontario, welding is an unrestricted trade; completion of an apprenticeship could take approximately 3 years including 3 periods of 8 weeks (720 hours) in-school theory. Upon successful completion of the training agreement, you will receive a Certificate of Apprenticeship.

What's Your Future as a Welder?

Most workers in this occupation work full-time, sometimes in shift work, usually indoors. Those with the ability to work with high-technology welding applications may have better employment opportunities. The bulk of employment opportunities are predicted to occur in the non-electrical, machinery, construction and metal-fabricating industries. Some workers will become self-employed. Examples of companies that employ welders include:

- Fabricating shops;
- Manufacturers of structural steel and **platework;**
- Construction industries;
- Boilers;
- Heavy machinery contractors;
- Aircraft contractors;
- Ship building and other transportation contractors;
- Specialized welding shops.

Wage Rate

- as an apprentice you would start at a wage rate less than that of a **journeyperson**
- this rate increases gradually as you gain competency
- the wage range for fully qualified welders according to the Peel Halton Dufferin HRDC Wage Book is between $9.50/hr to $16.18/hr, with a median salary of $12.50/hr.

1.9 After reading activity

Revise the information of Unit1 and make a list of the things welders should be able to do and places they can work at.

1.10 Lead-in

You already know what sort of skills you should have to be a welder. Now think of the answers to the following questions:

1. How long should a person be trained to become a skilled welder?
2. Do you think that a welder should be able to use all kinds of welding?

1.11 Speaking

Imagine you are a trying to choose a welding course to your needs. Which one will you choose if your needs are like these:

1. You have to know how to carry out mechanical tests.
2. You are interested in welding ferrous alloys and non ferrous alloys.
3. You want to introduce computers in your welding process.
4. You are new to welding and would like to be introduced to basic welding processes.
5. You want to learn how to choose the right type of welding for your specific purposes.
6. You want to be a highly qualified and certified expert in the field of welding.
7. You want to be familiar with welding standards

1.12 Reading

Welding Education and Consultation Training Centre

Course	Course Objectives	Course Outlines
Welding	The main objective of this	Materials properties related to

Design	course is to introduce welding engineers to the subject of welding design.	welding. Welding process selection. Types of welded joints. Welding Accessibility
	Many factors have to be considered in this issue. These factors include: consumer requirement, technical specifications, and environmental and economical constrains	and Inspection. Economical Analysis. Design information. Welding symbols. Case studies.
Welding Fundamentals	The main objective of this course is to familiarize engineers and inspectors to various aspects related to welding techniques, inspection and quality procedures in welding industry. The course is designed for engineers of scientists with no or little experience in the welding field.	Welding processes: Shielded metal Arc welding, Arc welding, Gas tungsten Arc welding, Submerged Arc welding & Oxyfuel welding & electric resistance. Cutting processes: Oxygen cutting, plasma cutting and laser cutting. Inspection of weldments: Nondestructive testing of welments. Mechanical testing of weldments (tensile, bending, impact).
Welding Inspection	The course discusses both qualification inspections and on-line inspections of welded joints. These include mechanical tests (tension, bending, impact, ...etc, and non destructive tests.	Significance of weld discontinuities. Welding inspection (non-destrutive testing techniques: surface inspection, magnetic particle, volumetric, radiography, and ultrasonic). Destructive testing techniques: hardness, tension, bending, ...etc. The control of quality during shop operations. The control of quality during site welding.
Non Destructive testing Certification:	Level I: Is to train inspectors to be able to pass level I examination and to be able to inspect using the chosen	Physical principals of test. Processing. Test equipment and materials. Codes, standards, procedures and

Magnetic Particle & Liquid Penetrant Testing (MT & PT)	technique. Level II: Is to upgrade level I inspectors to be able to pass level II examination and to be able to inspect, write a report, etc in the chosen technique.	safety. Test physical principals. Equipment and radiation source. Radiographic recording. Work parameters and conditions. Defectology. Selection of techniques. Test methods according to standards. Personal safety and protection.
Welding Metallurgy	The course delineates the main changes in the microstructure and/or the morphology of the metals and alloys during welding that lead to changes in properties. Alloys discussed in the course include all types of steels, Cast Iron, Nickel, Copper alloys, ...etc	Heat flow in welding. Effect of pre-and-post weld heat treatment. Introduction to welding metallurgy (hardenability and weldability). Metallurgy of steels. Welding of ferrous alloys: Carbon-steels, Low alloy steels, Stainless steels, and Cast Iron. Welding of non ferrous alloys: Al- Ni- and Cu-alloys. Identification and specifications of welding filler metals. Case studies.
Welding Quality Assurance	For each application, the welding process is controlled by specific code or standard. The course includes discussions of ASME boiler and pressure vessel code AWS steel structure code and other standards.	Welding co-ordination: tasks & responsibility. Quality requirements for welding. Qualification of welding procedures and welders. International codes and standards. Mechanical testing of welds. Non-destructive testing of welds. Documents for weld quality assurance. Case studies.
Welding Techniques	Selection of the welding process is very important. The course discusses the variables of each welding process and gives directions for selecting the proper	Overview of welding techniques and processes. Conventional techniques: arc, Oxy fuel and resistance welding. Non-conventional: plasma, electron beam, laser

	process for specific application. Welding processes discussed include: SMAW, GMAW, GTAW, etc.	welding. Flame and arc cutting of metals. Computer applications in welding. Case studies.
AWS Certified welding Engineer	The highest level of certification in the field of welding	To get certified as a welding engineer you need to attend four exams: Fundamentals of science. Applied science. Fundamentals of welding. Applied welding.

1.13 Writing

Write a short summary about a welder's competence. Cover the following areas:

- *welding courses welders can take;*
- *types of welding welders should be able to use,*
- *testing techniques welders should know about.*

1.14 Lead-in

Before you read, think of the following questions:

1. What does it mean to be a surface welder?
2. When does it become necessary to weld underwater?
3. Do you consider underwater welding an interesting career opportunity?

1.15 While-reading activity

Think of the answers to the following questions:

1. How can you *communicate to your company?*
2. What can be *a source of helpful information* for a welder? 3. Who can be called *a certified welder?*
4. How do people *apply for employment?*
5. What professions are *physical demanding?*
6. What kind of *career goals* may a welder have?
7. What is *formal training?*

1.16 Reading

Give the Ukrainian equivalents for the word combinations in italics in the text

Taking the Plunge

Over the years, a number of people have expressed an interest in careers in underwater welding, but were unsure how to get started. Welders, students, divers, and other interested men and women have contacted the American Welding

Society (AWS) for guidance. In order to help those prospective underwater welder-divers, the D3B *Subcommittee on Underwater Welding* has provided answers for some commonly asked questions.

1. What skills are prerequisite to entering the field of underwater welding?

The skills suggested for entering the field of underwater welding can best be defined by the following typical description of a welder-diver from the AWS D3.6 Standard. "Welder-diver: A *certified welder* who is also a **commercial** diver, capable of performing tasks associated with commercial **subsea** work, weld setup and preparation, and who has the ability to weld in accordance with the AWS D3.6." By description, an experienced welder-diver must possess: *commercial diving skills* (i.e., be familiar with the use of specialized commercial diving equipment, have an understanding of diving physiology, diving safety, **rigging**, the underwater environment, communication, etc.); weld setup and preparation skills (i.e., the ability to perform tasks typically assigned to a **fitter** or rigger, such as materials **alignment** and materials preparation including **beveling**, **stripping** of concrete, fitting a steel **patch** or repair plate, etc.,); and the ability to certify to a required underwater weld procedure.

2. I am a certified surface welder, what other training do I need to qualify as a welder-diver?

The majority of work performed by an average welder-diver does not involve the welding operation itself, but rather executing the tasks that lead up to and follow the *actual welding activities*. Except under special circumstances, a welder-diver in most cases must posses both certified welder skills and commercial diving skills. It is suggested that if you have no prior commercial diving experience you should attend one of the recognized commercial diving schools. The candidate may be required to pass a diving physical prior to *school acceptance* and in some cases a written exam. It is suggested that a dive physical be taken regardless, to avoid going through the expense of training only to later find you have a disability that prevents your entering the profession. Once that basic commercial diver training is completed, it is common practice *to apply for employment* at one of many commercial diving companies that offer underwater welding as a service. An interview with the company of your choice is recommended to express your *career goals* in underwater welding and past welding experience. Expect to begin your career as a *diver tender* (*apprentice diver*) initially. As a diver tender you will gain valuable practical experience while learning the trade.

3. I am already a certified diver, what other training do I need to qualify as a welder-diver?

The welding processes, classes of weld and qualification tests associated with underwater welding are described in ANSI/AWS D3.6. We recommend the specification as a reference for weld procedure and welder qualification. It is also a good *source of other helpful information*. If you are already certified as a "commercial diver" and work for a company that offers underwater welding services, it is recommended that you *communicate to your company* your career objectives and ask what welder skills they are looking for. If you are certified as a "**scuba diver**", it is suggested that you attend a commercial diving school. Sport dive training does not include the safe use of commercial diving equipment, offshore commercial work environment/safety, and other education. Underwater welding is a skill you also have to master once you obtain the basic commercial diving skills required.

4. What are the age limitations of a welder-diver?

There is no age restriction on commercial welder-divers. There are, however, physical requirements. It is recommended and generally required that all commercial divers pass an annual dive **physical**. The commercial diving profession is *physical demanding*. It is rare to see an active commercial welder-diver over the age of 50.

5. What salary can I expect to make as a welder-diver?

We know some welder-divers earn $15,000 per year while others earn in excess of $100,000. Because the majority of welder-divers are paid on a *project-by-project basis,* salaries are subject to the same variables as work availability. In addition, other factors such as depth, dive method and diving environment affect pay rates. The company with whom you gain employment should be able to tell you the salary range you can expect to earn.

6. What other skills are recommended to supplement my qualifications as a welder-diver?

Ideally, a diving contractor would like its welder-divers to be "a jack of all trades and a master of them all!" Practically speaking, possessing the skills that are common to underwater welding operations, in addition to welding and diving, are recommended. Primarily these skills are: underwater cutting (**oxyfuel**, abrasive water jet, mechanical cutting equipment, etc.); fitting and rigging; inspection and nondestructive testing (visual, magnetic particle, ultrasonics, radiography, eddy current, etc.); drafting; and underwater photography (still photo and video). The more skills the welder-diver maintains the more valuable he becomes in meeting project qualification requirements. The most desirable underwater welder-divers are those who are qualified to: assist the diving contractor in pre-job planning (e.g., having the ability to photograph/video, **draft** and report on *work requirements* prior to the actual underwater welding operation); cut, clean, rig, install, and fit up the sections they will weld; and work with personnel responsible for inspecting the completed welds. *Formal training* is recommended for whatever skills you wish to qualify for. Maintaining the qualifications you obtain is just as important as receiving them as there has been many a job lost to a welder-diver who has **let his certification lapse.**

7. What future career opportunities are there for an experienced welder-diver?

There are a number of career opportunities for experienced welder-divers. Many go on to become engineers, instructors, and diving operations supervisors, *fill management positions*, qualify as AWS Certified Welding Inspectors (CWI), and serve as consultants for underwater welding operations and other related fields. Ideally, a career as a welder-diver should serve as a *stepping stone* to other opportunities for those who choose the profession. Industry has and will continue to demand higher quality standards for underwater welds and more certification of underwater welding systems and personnel.

1.17 After-reading activity

Continue filling in the following table:

Operations both surface and welder-divers do	**Operations only welder-divers do**
weld setup and preparation, …	underwater cutting, …

1.18 Speaking

Correct the following statements to make them correspond to the text:

1. Welder-divers must have the skills of commercial diving but need not be certified.
2. The majority of work performed by an average welder-diver includes only welding operation itself.
3. Welder-divers apply for employment at commercial diving companies before their diver training is completed.
4. Commercial welder-diver is the same as scuba diver.
5. You cannot be a welder-diver if you are over 50 years old.
6. To possess commercial diving skills means to be able to do underwater weld procedures.
7. Welder-divers earn from $15,000 to $100,000 per year depending on their work experience.
8. To pass a physical examination for welder diver you need to go through formal training.
9. Past welding experience doesn’t count if you choose to be a welder-diver.

Answer the following questions:

1. Who can be a welder-diver?
2. What sorts of basic and supplementary skills must a welder-diver possess?
3. How can certified surface welders become welder-divers?
4. What is more important: receiving the welder-diver qualifications or maintaining them?
5. Why do commercial divers pass an annual dive physical?
6. Do welder-divers have any future career opportunities?
7. Do you think surface welding equipment can be used underwater?

Think and say:

1. The word combination *taking the plunge* is a set phrase (связанное фразеологическое сочетание). Is it a good title for this text? Why?

2. Another set phrase in the text is *a stepping stone*. What are possible stepping stones in your welding career?

2 THE HISTORY OF WELDING

2.1 Lead-in

Think of the answers for the following questions:

1. Why did welding become necessary?
2. Is welding a new profession?
3 Who were the first welders?
4. Who invented modern welding?

2.2 Reading

Welding History

Joining metal and welding history go back several millennia starting in the Bronze Age then Iron Age in Europe then the Middle East. Welding was used in the Iron pillar in Delhi, India, about 310 AD, weighing 5.4 metric tons (picture at left). The Middle Ages brought forge welding, blacksmiths pounded hot metal until it bonded. In 1540, Vannoccio Biringuccio released De la pirotechnia, which includes descriptions of the forging operation. Renaissance craftsmen gained skilled in the process, and the welding continued to grow during the following centuries.

Welding was transformed during the 19th century. In 1800, Sir Humphrey Davy invented the electric arc, and advances in welding continued with the metal electrode by a Russian, Nikolai Slavyanov, and an American, C.L. Coffin late in the 1800s.

Acetylene was discovered in 1836 by Edmund Davy, but was not practical in welding until about 1900, when a suitable blowtorch was developed. At first, oxyfuel welding was the more popular welding method due to its portability and relatively low cost. As the 20th century progressed, it fell out of favor for industrial applications. It was largely replaced with arc welding, as metal coverings (known as flux) for the electrode that stabilize the arc and shield the base material from impurities continued to be developed.

In 1881 a Russian inventor, Benardos demonstrated the carbon electrode welding process. An arc was formed between a moderately consumable carbon electrode and the work. A **rod** was added to provide needed extra metal.

Resistance welding was developed during the end of the 19th century, with the first patents going to Elihu Thompson in 1885, and he produced advances over the next 15 years.

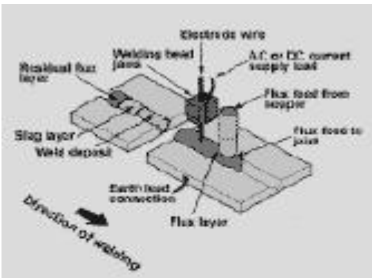
In 1904 Oscar Kjellberg in Sweden, who started ESAB, invented and patented the covered electrode. This electric welding process made strong welds of excellent quality.

World War I caused a major surge in the use of welding processes, with the various military powers attempting to determine which of the several new welding processes would be best. The British primarily used arc welding, even constructing a ship, the Fulagar, with an entirely welded hull. The Americans were more hesitant, but began to recognize the benefits of arc welding when the process allowed them to repair their ships quickly after a German attack in the New York Harbor at the beginning of the war. Arc welding was first applied to aircraft during the war as well, as some German airplane fuselages were constructed using the process.

During the 1920s, major advances were made in welding technology, including the introduction of automatic welding in 1920, in which electrode wire was fed continuously.

Shielding gas became a subject receiving much attention, as scientists attempted to protect welds from the effects of oxygen and nitrogen in the atmosphere. Porosity and brittleness were the primary problems, and the solutions that developed included the use of hydrogen, argon, and helium as welding atmospheres.

During the following decade, further advances allowed for the welding of reactive metals like aluminum and magnesium. This, in conjunction with developments in automatic welding, alternating current, and fluxes fed a major expansion of arc welding during the 1930s and then during World War II.



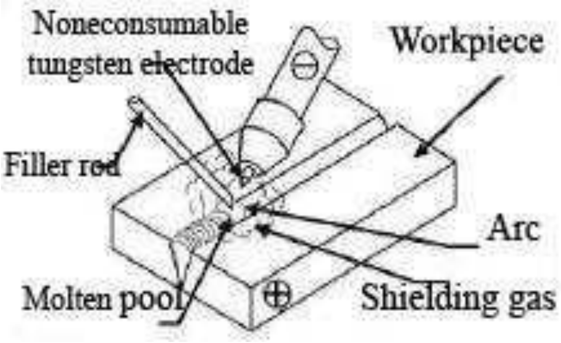
A significant invention was defined in a patent by Alexander, filed in December 1924, and became known as the Atomic Hydrogen Welding Process. It looks like MIG welding but hydrogen is used as the shielding gas which also provides extra heat.

A major innovation was described in a patent that defines the Submerged Arc Process by Jones, Kennedy and Rothermund. This patent was filed in October 1935 and assigned to Union Carbide Corporation. The following was excepted from an article written by Bob Irving in he Welding Journal: “The importance of welding was emphasized early in the war when President Roosevelt sent a letter to Prime Minister Winston Churchill, who is said to have read it aloud to the members of Britain's House of Commons. The letter read in part, "Here there had been developed a welding technique (referring to **Submerged Arc Welding**) which enables us to construct standard merchant ships with a speed unequalled in the history of merchant shipping."

Russell Meredith working at Northrop Aircraft Company in 1939-1941 invented the TIG process. This new process was called "Heliarc" as it used an electric arc to melt the base material and helium to shield the molten puddle. Mr.Jack Northrop's dream was to build a magnesium airframe for a lighter, faster warplanes and his welding group invented the process and developed the first TIG torches. The patents were sold to Linde who developed a number of torches for different applications. They also developed procedures for using Argon which was more available and less expensive than Helium.

In 1957, the flux-cored arc welding process debuted, in which the self-shielded wire electrode could be used with automatic equipment, resulting in greatly increased welding speeds, and that same year, plasma arc welding was invented. Electroslag welding was released in 1958, and it was followed by its cousin, electrogas welding, in 1961.

Other recent developments in welding include the 1958 breakthrough of electron beam welding, making deep and narrow welding possible through the concentrated heat source. Following the invention of the laser in 1960, laser beam welding debuted several decades later, and has proved to be especially useful in high-speed, automated welding.



Both of these processes, however, continue to be quite expensive due the high cost of the necessary equipment, and this has limited their applications.

2.3 After-reading activity

Match the dates, names and inventions from the following table:

1540	Vannoccio Biringuccio	discovered acetylene
1800	Sir Humphrey Davy	invented the electric arc
1800s.	Nikolai Slavyanov, C.L. Coffin	developed metal
1836	Edmund Davy	brought a coated metal electrode
1881	A. P. Strohmenger	invented and patented the covered electrode
1900	Benardos	described forging operation
1904	C.J. Holslag	invented alternating current
1919	Oscar Kjellberg	demonstrated the welding process with carbon electrode
1935	Jones, Kennedy and Rothermund	developed Submerged Arc Welding
1924	Alexander	patented Atomic Hydrogen Welding process

2.4 After-reading discussion

True or false?

1. Arc welding was used to build the Iron pillar in Delhi, India.
2. The discovery of acetylene made it possible to achieve higher heating temperatures.
3. The first electrode used in welding was a covered one.
4. The British Prime Minister Winston Churchill was a famous welder.
5. Oxygen is used as shielding gas in TIG welding.
6. The TIG process made it possible to construct planes faster.

Answer the following question on the text:

1. Which process was developed earlier, MIG or TIG?
2. Why is rod added in carbon electrode welding?
3. What is the difference between the Atomic Hydrogen Welding process and the MIG process?
4. What kind of gas was first used to shield the molten puddle?
5. Is tungsten electrode consumable?

2.5 Reading

Interesting Facts About Welding

Welding is a technique used for joining metallic parts usually through the application of heat. This technique was discovered during efforts to manipulate iron into useful shapes. Welded blades were developed in the first millennium AD, the most famous being those produced by Arab armourers at Damascus, Syria. The process of carburization of iron to produce hard steel was known at this time, but the resultant steel was very brittle. The welding technique - which involved interlayering relatively soft and tough iron with high-carbon material, followed by hammer forging - produced a strong, tough blade.

In modern times the improvement in iron-making techniques, especially the introduction of cast iron, restricted welding to the blacksmith and the jeweler. Other joining techniques, such as fastening by bolts or rivets, were widely applied to new products, from bridges and railway engines to kitchen utensils.

Modern fusion welding processes are an outgrowth of the need to obtain a continuous joint on large steel plates. Rivetting had been shown to have disadvantages, especially for an enclosed container such as a boiler. Gas welding, arc welding, and resistance welding all appeared at the end of the 19th century. The first real attempt to adopt welding processes on a wide scale was made during World War I. By 1916 the oxyacetylene process was well developed, and the welding techniques employed then are still used. The main improvements since then have been in equipment and safety. Arc welding, using a consumable electrode, was also introduced in this period, but the bare wires initially used produced brittle welds. A solution was found by wrapping the bare wire with asbestos and an entwined aluminum wire. The modern electrode, introduced in 1907, consists of a bare wire with a complex coating of minerals and metals. Arc welding was not universally used until World War II, when the urgent need for rapid means of construction for shipping, power plants, transportation, and structures spurred the necessary development work.

Resistance welding, invented in 1877 by Elihu Thomson, was accepted long before arc welding for spot and seam joining of sheet. Butt welding for chain making and joining bars and rods was developed during the 1920s. In the 1940s the tungsten-inert gas process, using a nonconsumable tungsten electrode to perform fusion welds, was introduced. In 1948 a new gas-shielded process utilized a wire electrode that was consumed in the weld. More recently, electron-beam welding, laser welding, and several solid-phase processes such as diffusion bonding, friction welding, and ultrasonic joining have been developed.

2.6 After-reading activity

Refer the following statements to each of the passages of the text:

1. Application of welding techniques is decreasing nowadays.
2. Welding originated from the attempts to shape metal into useful forms.
3. Resistance welding is one of the earliest types of joining metals.
4. Industrial development in the 1950-s expedited (ускорять) the advance of welding technologies.

2.7 Speaking

True or false?

1. Only heat is used for joining metallic parts in welding.
2. The process of carburization of iron is rather new.
3. The blacksmith and the jeweler continue to use welding techniques in their work.
4. Welding is the only technique of joining metallic parts.
5. The modern electrode consists of a bare wire with asbestos.
6. Arc welding was not used after World War II.
7. Diffusion bonding and friction welding are solid-phase processes.
8. Rivetting is now widely used for producing an enclosed container such as a boiler.

Answer the following questions:

1. What is welding?
2. How was welding discovered?
3. Who were the first welders?
4. What did the first welding technique for making blades involve?
5. Did the improvement in iron-making techniques conduce to the development of welding?
6. Is it efficient to apply riveting for making boilers?
7. When did gas, arc and resistance welding appear?
8. What was the quality of the welds produced by the arc welding using bare wires like?
9. What does the coating of the modern electrode consist of?

10. What are the years 1877, 1916, and 1948 remarkable for in terms of welding?

2.8 Writing

Write a short report on the history of welding mentioning:

Dates: first millennium AD, 1540, 1800, 1836, 1881, , 1877, 1881, 1892, 1900, 1904, 1907, 1924, 1935, 1948.
Names: Alexander, Jones, Kennedy and Rothermund, Morehead and Wilson, Oscar Kjellberg, Benardos, Russell Meredith, Edmund Davy, Nikolai Slavyanov, C.L. Coffin, Vannoccio Biringuccio, Sir Humphrey Davy.
Places: Syria, Russia, Sweden, the US, Britain;
Inventions: modern electrode, resistance welding, oxyacetylene process, MIG, TIG, atomic hydrogen welding process, submerged arc welding, carbon electrode.

2.9 Lead-in

Think of the answers for the following questions:

1. How can welding influence the history of a country?
2. In what fields of industry, in your opinion, is welding especially important?
3. What modern machines and structures cannot be produced without welding processes?
4. What welding process, arc or gas ones, has played a more important part in developing new technologies? What particular aspect(s) of this process/processes is/are of significance for industry development?

2.10 Pre-reading activity

Find the following figures in the text and say what they relate to:
140, 20, 5171, 2200, 1945, 525, 531, 2710, 250,000, 58, 117, 1915, 1931, 1977, 120, 176,000, 500,000, 586,000, 17,000, 80, 373,500, 52.

2.11 Reading

Welding's Vital Part In American Historical Events

Shipbuilding

The finest hours for U.S. shipbuilding were during World War II when 2710 Liberty ships, 531 Victory ships and 525 T-2 tankers were built for the war effort. Through 1945, some 5171 vessels of all types were constructed to American Bureau of Shipping (ABS) class during the Maritime Commission wartime shipbuilding program. At this time in shipbuilding history, welding was replacing riveting as the main method of assembly.

The importance of welding was emphasized early in the war when President Roosevelt sent a letter to Prime Minister Winston Churchill, who is said to have read it aloud to the members of Britain's House of Commons. The letter read in part, "Here there had been developed a welding technique which enables us to construct standard merchant ships with a speed unequaled in the history of merchant shipping."

The technique the President was referring to was undoubtedly submerged arc welding, which was capable of joining steel plate as much as 20 times faster than any other welding process at that time.

During this period of assimilation, eight Liberty ships were lost due to a problem called brittle fracture. At first, many blamed welding, but history would soon prove that the real cause of brittle fracture was steels that were notch sensitive at operating temperatures. The steel was found to have high sulfur and phosphorus contents. On more than 1400 ships, crack arrestors were used to prevent crack propagation. No crack was known to grow pastan arrestor. This safeguard helped reduce casualties from 140 to 20 per month.

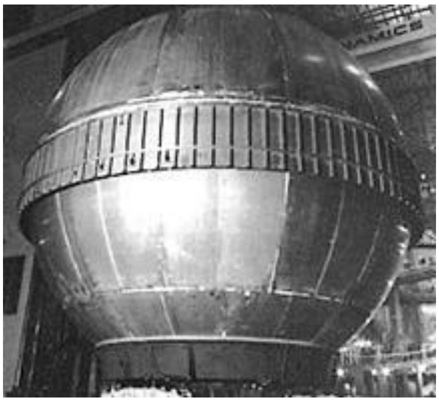
The ASME Code

In the late 1920s and early 1930s, the welding of pressure vessels came on the scene. Welding made possible a quantum jump in pressure attainable because the process eliminated the low structural efficiency of the riveted joint. Welding was widely utilized by industry as it strove to increase operating efficiencies by the use of higher pressures and temperatures, all of which meant thick-walled vessels. But before this occurred, a code for fabrication was born from the aftermath of catastrophe.

On April 27, 1865, the steamboat Sultana blew up while transporting 2200 passengers on the Mississippi River. The cause of the catastrophe was the sudden explosion of three of the steamboat's four boilers, and up to 1500 people were killed as a result. Most of the passengers were Union soldiers homeward bound after surviving Confederate prison camps. In another disaster on March 10, 1905, a fire tube boiler in a shoe factory in Brockton, Mass., exploded, killing 58, injuring 117 and causing damages valued at $250,000. These two incidents, and the many others between them, proved there was a need to bring safety to boiler operation. So, a voluntary code of construction went into effect in 1915 - the ASME Boiler Code.

As welding began to be used, a need for nondestructively examining those welds emerged. In the 1920s, inspectors tested welds by tapping them with hammers, then listening to the sound through stethoscopes. A dead sound indicated a defective weld. By 1931, the revised Boiler Code accepted welded vessels judged safe by radiographic testing. By this time, magnetic particle testing was used to detect surface cracks that had been missed radiographic testing. By this time, magnetic particle testing was used to detect surface cracks that had been missed by radiographic inspection. In his history of the ASME Code, A. M. Greene, Jr., referred to the late 1920s and early 1930s as "the great years." It was during this period that fusion welding received widespread acceptance. Nowadays, thousands of individuals who make their living in welding live and breathe the ASME Code every minute of the working day.

In 1977, Leonard Zick, chairman of the main committee of the ASME Code, said, "It's more than a code; the related groups make up a safety system. Our main objective is to provide requirements for new construction of pressure-related items that, when followed, will provide safety to those who use them and those who might be affected by their use. "



LNG Tankers

A triumph of the code was the huge aluminum spheres built by General Dynamics in Charleston, S.C. They were built to criteria established by the U.S. Coast Guard and were based on Section VIII, Division 1, of the ASME Code.

At about 2 a.m. on October 2, 1976, the first welded aluminum sphere for a liquefied natural gas tanker was rolled out of a building in Charleston, then moved over to a special stand for final hydropneumatic testing. It soon passed the test with flying colors. The sphere itself weighed 850 tons and measured 120 ft (36 m) in diameter. Each sphere consisted of more than 100 precisely machined plates, "orange peel" in shape. The plates were gas metal arc welded together using 7036 lb (3166 kg) of filler metal. Total length of the welds on each sphere was 48.6 miles. Completed spheres were barged along the coast and delivered onto steel tankers under construction at General Dynamics' shipyard in Quincy, Mass. This type of LNG tanker was based on the Moss-Rosenberg design from Norway.

At General Dynamics' facility in Charleston, 80% of the metalworking manhours were spent welding. Much of the filler metal deposited in Charleston was 5183 aluminum. The vertical joints were welded using special equipment from Switzerland in which the operator rode in a custom-designed chair alongside the welding arc. At this distance, he was able to monitor the weld and observe the oscillation of the 1Z.5 -mm diameter filler metal. Actual welding was controlled remotely. About 30 weld passes were required for each joint.

The massive equatorial ring was welded outdoors. In this setup, nine heavily machined, curved aluminum extrusions had to be welded together. To do it, 88 GMA weld passes were made from the outside and 60 more from the inside.

The Alaska Pipeline

Perhaps no single welding event in history ever received so much attention as did the Alaska Pipeline. Crews of seasoned welders braved Alaska's frigid terrain to weld this large-diameter pipeline, from start to finish. At one point, 17,000 people were working on the pipeline - 6% of the total population of Alaska. The entire pipeline only disturbed about 12 square miles of the 586,000 square miles of the state of Alaska.

Welders were called upon to handle and weld a new steel pipe thicker and larger than most of them had ever encountered before, using electrodes also new to most. And, the requirements were the stiffest they had ever seen.

The U.S. Department of the Interior and a new pipeline coordinating group representing the state of Alaska instituted some changes. So, the original specifications for field welding were tossed, replaced by much stiffer requirements for weld toughness. Instead of the conventional pipeline welding electrode planned originally for the bulk of field welding, the new requirements required higher quality. The only electrode the engineers could find that met the new requirements was an E8010-G filler metal from Germany, so it was soon flown over by the planeload. Some of the Pipeline Welders Union out of Tulsa, Okla., then welding in Alaska, had used this electrode while working on lines in the North Sea, but most welders were seeing it for the first time.

One of the requirements was 100% X-ray inspection of all welds. The films were processed automatically in vans that traveled alongside the welding crews.

Welders worked inside protective aluminum enclosures intended to protect the weld joint from the wind. Lighting inside the enclosures enabled welders to see what they were doing during Alaska's dark winter.

On the main pipeline, preheat and the heat between weld passes was applied at first by spider-ring burners. Induction heating was used later during construction.

High-Rise Construction

About 30 years ago, steel construction went into orbit. The 100-story John Hancock Center in Chicago and the 110-story twin towers of New York's World Trade Center were under construction. Above ground, the World Trade Center required some 176,000 tons of fabricated structural steel. The Sears Tower came later. Bethlehem Steel Corp. had received orders for 200,000 tons of rolled steel products for the South Mall complex in Albany, N.Y. Allied Structural Steel Co. was reported to have used multiple-electrode gas metal arc welding in the fabrication of the First National Bank of Chicago Building.

In a progress report on the erection of the critical corner pieces for the first 22 floors of the 1107-ft (332-m) high John Hancock Center, an Allied Structural Steel spokesman said various welding processes were being used in that portion of the *high-rise building*. More than 12,000 tons of structural steel were used in that section. Webs and flanges for each *interior H column* were made up of A36 steel plate with thicknesses up to 6172 in. (16.5 cm). The long fillet welds at the web-to-flange contact faces were made using the submerged arc process, while the box consumed in shop fabrication for this building, while 165,000 lb (74,250 kg) of weld metal was consumed during field erection. Weld *metal consumption* in shop fabrication for the U.S. Steel Building in Pittsburgh, Pa., reached 609,000 lb (274,050 kg).

During this same period, Kaiser Steel Corp. had used the consumable guide version of electroslag welding to deposit 24,000 welds in the Bank of America world *headquarters building* in San Francisco. At the time, this building was regarded as the tallest *earthquake-proof* structure ever erected on the West Coast. In terms of welding, one of the most intensive structures built during this period was NASA's Vertical Assembly Building on Merritt Island, Fla. Shop-welded sections for this giant structure consumed 830,000 lb (373,500 kg) of weld metal.

For the World Trade Center, Leslie E. Robertson, a partner in charge of the New York office of Skilling, Helle, Christiansen, Robertson, said a computer was used to produce the drawing lists, beam schedules, column details and all schedules for exterior wall panels. Millions of IBM cards were then sent to every fabricator. These cards gave fabricators the width, length, thickness and *grade* of steel of every plate and section in all of the columns and panels. "In addition," he said, "the fabricators are given all of the requirements of every weld needed to make up the columns and panels. Many of these cards are used as equable to the production of drawings. They are sent directly from the designer to the fabricators. Draftsmen never become involved."

Elsewhere in New York City, Leo Plofker, a partner in one of the city's leading design engineering firms, extensively used welding in design. Among Plofker's achievements are the Pan-Am Building and the all-welded, 52-story office building known as 140 Broadway. "Our decision to make extensive use of welding is strictly based on economics," he said. "Welded design results in savings in steel. Field welding can cause some problems, but they are not too serious as long as you maintain control over the welders and you insist that qualified personnel be employed to perform nondestructive testing of the welds."

2.12 After-reading activity

Find the following sentences in the text and express in your own words what they mean:

1. Nowadays, thousands of individuals who *make their living in welding* live and *breathe the ASME Code every minute of the working day.*
2. A. M. Greene, Jr. referred to the late 1920s and early 1930s as *"the great years."*
3. About 30 years ago, steel construction *went into orbit*.
4. Welded design results in savings in steel.
5. In the late 1920s and early 1930s, the welding of pressure vessels *came on the scene*.
6. In 1977, Leonard Zick, chairman of the main committee of the ASME Code, said, “*It's more than a code…* ;”

Fill in the blanks:

1. Before welding, … was the main assembly method in constructing standard merchant ships.
2. … was the fastest welding process for joining steel plate in 1940s.
3. The first quality inspectors used … to tap the metal and hear the noise.
4. The use of higher pressures and temperatures made it necessary to construct … vessels.
5. Magnetic particle testing was more efficient than radiographic testing in detecting … .
6. The use of IBM cards during the construction of the World Trade Center made it possible not to involve … .
7. In case of **X-**ray inspection one has to process … .

2.13 Speaking

True or false?

1. In 1940s all the welding techniques known were fast enough to produce ships.
2. Americans lost a lot of ships because of problems associated with welding.
3. Introduction of welding into the high pressure and temperature structures construction made it possible to make a great advance in industry.
4. The ASME Code was introduced to ensure safety in boiler production.
5. Draftsmen played an important part in the construction of the World Trade Center.

3 WELDING PROCESSES AND EQUIPMENT

3.1 Lead-in

You already know what kind of training you should go through to become welder. Among other things, a welder should know about processes which are similar to welding. Look through the vocabulary and the text below and say what the main difference between welding and related metal joining processes is.

3.2 Reading

Introduction to Welding Processes and Equipment

Among the first things a new welder needs to understand, is what the different kinds of welding processes and equipment are, and their application. A quick rundown:

Terms:

Soldering: Bonding by melting a soft metal to the surface of pieces to be joined. Low temperature. Good for joining dissimilar materials. Most common solders are lead-tin alloys.

Tinning: A soldering process, where the surface of a metal is coated with solder.

Leading: A form of soldering, solder is used to fill in the surface of metal.

Brazing: Similar to soldering, but uses a higher temperature to fuse the filler metal to the work pieces. Stronger bond. (Includes "Silver Soldering") Work heated to pre-melt temperatures.

Welding: Joining 2 similar work pieces by melting them together, usually with an additional filler rod of some sort to take up space. Materials must be similar.
Cutting: Work is heated to melting point and beyond, and "cut" by oxidizing metal. (Literally burning it away).
Shield: A barrier to keep oxygen away from heated work to prevent oxidation. Includes chemical coatings called **flux** (liquids, pastes, solids, which may be vaporized into a barrier gas when heated), and inert gasses. Oxidation of the surfaces will prevent proper bonding of the metals.

Gas Welding

Uses Flame from burning gas to create welding heat.
Propane torch: (*Soldering, heating)* Good for sweating pipes, starting fires, and spending hours trying to heat frozen bolts, while the surrounding metal gets just as hot.
Oxyacetylene torch: (*Cutting, welding, brazing, soldering, leading)* Most universal and useful welding tool. (Uses Acetylene gas and Oxygen for hot flame) With the right bits, rod, and technique, you can weld almost anything. Good for cutting anything from sheet metal to the turret off a tank, lead filling, brazing (a sort of hard soldering process) welding plate, welding sheet metal, welding aluminium, heating frozen bolts, or alternately cutting them off, drilling holes in plate, welding cast iron, shrinking and forming steel, and can double as a flame thrower in a pinch. Drawbacks are: Overheating of some types of work, harder to control quality of some processes.
Oxy-propane: (*Soldering, brazing, heating)* A cheap compromise between low cost and portable propane, and Oxy-Acetylene. Better than the former, not as good as the latter.

Arc Welding

Uses an electric arc to create welding heat.
Basic AC & DC arc welders (AC is cheaper) Uses flux coated steel (or other) rods of various types for different jobs. Makes some of the best welds on heavy gauge steels and cast iron. Cutting rods can make clean holes through thick stock, and are about the only thing which can cut Kryptonite bike locks. Very difficult to weld thin metals. You can also get a **carbon arc torch** to use on an arc welder to braze. Eastwood's **"stitch" welder** is a gimmick used on an arc welder to buzz the rod in and out, which may help on thinner stock. (learning how to weld better, or going to a different process is usually a better idea.)
MIG (Metal Inert Gas): A DC arc welding process which uses filler metal fed in the form of a spool of thin wire, shielded by flow of inert gas (He, Argon) instead of flux used in Arc. Very fast, much easier than Arc Welding, with less **heat buildup**. Very good for sheet metal, due to minimal **heat distortion**. Harder to weld thick stock, as welds are weaker due to poorer penetration. The modern choice for steel body work, it can also be used for Aluminium with Argon as the shield gas.
TIG (Tungsten Inert Gas): A high frequency AC arc process which uses a tungsten electrode shielded by an inert gas to create a fine, controllable torch.

Uses a separate filler rod, as in Oxy-Acetylene welding. Capable of welding very thin metals. About the best process for Aluminium, Stainless steel, and other exotic stuff.

Resistance welding: includes **spot welding:** Uses the heat generated by electricity flowing through work to melt and fuse. i.e.- put an electrode on either side of 2 overlapped sheets of steel, turn on power. Metal in between heats up, and melts together. An old favorite for assembling car bodies.

Plasma Cutters: Not a welder, but related. A high voltage arc is used to superheat and ionize a stream of air to the "plasma" state. The stream of plasma makes a rapid, clean, narrow cut with minimal heating of the work piece.

3.3 After-reading activity

Answer the following questions:

1. What is the main difference between soldering and brazing?
2. What is used by welders to prevent oxidation?
3. What makes soldering advantageous before welding?
4. What welding processes are suitable for welding thin/thick metal plates?
5. What makes plasma cutting better than gas cutting?

3.4 Reading

Basic Principles of Welding

A weld can be defined as a coalescence of metals produced by heating to a suitable temperature with or without the application of pressure, and with or without the use of a filler material.

In fusion welding a heat source generates sufficient heat to create and maintain a molten pool of metal of the required size. The heat may be supplied by electricity or by a gas flame. Electric resistance welding can be considered fusion welding because some molten metal is formed.

Solid-phase processes produce welds without melting the base material and without the addition of a filler metal. Pressure is always employed, and generally some heat is provided. Frictional heat is developed in ultrasonic and friction joining, and furnace heating is usually employed in diffusion bonding.

The electric arc used in welding is a high-current, low-voltage discharge generally in the range 10–2,000 amperes at 10–50 volts. An arc column is complex but, broadly speaking, consists of a cathode that emits electrons, a gas plasma for current conduction, and an anode region that becomes comparatively hotter than the cathode due to electron bombardment. Therefore, the electrode, if consumable, is made positive and, if nonconsumable, is made negative. A direct current (dc) arc is usually used, but alternating current (ac) arcs can be employed.

Total energy input in all welding processes exceeds that which is required to produce a joint, because not all the heat generated can be effectively utilized. Efficiencies vary from 60 to 90 percent, depending on the process; some special processes deviate widely from this figure. Heat is lost by conduction through the base metal and by radiation to the surroundings.

Most metals, when heated, react with the atmosphere or other nearby metals. These reactions can be extremely detrimental to the properties of a welded joint. Most metals, for example, rapidly oxidize when molten. A layer of oxide can prevent proper bonding of the metal. Molten-metal droplets coated with oxide become entrapped in the weld and make the joint brittle. Some valuable materials added for specific properties react so quickly on exposure to the air that the metal deposited does not have the same composition as it had initially. These problems have led to the use of fluxes and inert atmospheres.

In fusion welding the flux has a protective role in facilitating a controlled reaction of the metal and then preventing oxidation by forming a blanket over the molten material. Fluxes can be active and help in the process or inactive and simply protect the surfaces during joining.

Inert atmospheres play a protective role similar to that of fluxes. In gas-shielded metal-arc and gas-shielded tungsten-arc welding an inert gas — usually argon—flows from an annulus surrounding the torch in a continuous stream, displacing the air from around the arc. The gas does not chemically react with the metal but simply protects it from contact with the oxygen in the air.

The metallurgy of metal joining is important to the functional capabilities of the joint. The arc weld illustrates all the basic features of a joint. Three zones result from the passage of a welding arc: (1) the weld metal, or fusion zone, (2) the heat-affected zone, and (3) the unaffected zone. The weld metal is that portion of the joint that has been melted during welding. The heat-affected zone is a region adjacent to the weld metal that has not been welded but has undergone a change in microstructure or mechanical properties due to the heat of welding. The unaffected material is that which was not heated sufficiently to alter its properties.

Weld-metal composition and the conditions under which it freezes (solidifies) significantly affect the ability of the joint to meet service requirements. In arc welding, the weld metal comprises filler material plus the base metal that has melted. After the arc passes, rapid cooling of the weld metal occurs. A one-pass weld has a cast structure with columnar grains extending from the edge of the molten pool to the centre of the weld. In a multipass weld, this cast structure may be modified, depending on the particular metal that is being welded.

The base metal adjacent to the weld, or the heat-affected zone, is subjected to a range of temperature cycles, and its change in structure is directly related to the peak temperature at any given point, the time of exposure, and the cooling rates. The types of base metal are too numerous to discuss here, but they can be grouped in three classes: (1) materials unaffected by welding heat, (2) materials hardened by structural change, (3) materials hardened by precipitation processes.

Welding produces stresses in materials. These forces are induced by contraction of the weld metal and by expansion and then contraction of the heat-affected zone. The unheated metal imposes a restraint on the above, and as contraction predominates, the weld metal cannot contract freely, and a stress is built up in the joint. This is generally known as residual stress, and for some critical applications must be removed by heat treatment of the whole fabrication. Residual stress is unavoidable in all welded structures, and if it is not controlled bowing or distortion of the weldment will take place. Control is exercised by welding technique, jigs and fixtures, fabrication procedures, and final heat treatment.

3.5 After-reading activity

Complete the following sentences:

1. A characteristic feature of fusion welding is:
a) molten metal b) low-voltage discharge c) inert atmosphere
2. Furnace heating is usually employed in
a) friction joining b) diffusion bonding c) ultrasonic joining
3. The consumable electrode is made
a) negative b) positive c) neither
4. Total energy input in all welding processes is
a) is greater than required to produce a joint b) is smaller than required to produce a joint c) equals to required to produce a joint
5. Reactions of most metals with the atmosphere or other nearby metals can
a) improve the properties of a welded joint b) make the properties of a welded joint worse c) never influence the properties of a welded joint
6. The most common gas used in gas-shielded metal-arc and gas-shielded tungsten-arc welding is
a) argon b) oxygen c) carbon dioxide
7. If not controlled, residual stress results in
a) precipitation processes in welded structures, b) freezing of the weld-metal c) bowing or distortion of the weldment.

True or false?

1. There is always a welding pool in solid-phase welding processes.
2. Total energy input in all welding processes is greater than needed to produce a weld.
3. Reactions of metals with the atmosphere or other nearby metals are favorable to the properties of a welded joint.
4. Fluxes and inert atmospheres play a protective role and prevent oxidation.
5. The heat-affected zone is a region with unaltered properties.
6. Residual stress is present in all welded structures.

Answer the following questions:

1. What is a weld?
2. How can the heat be supplied for welding?
3. Is pressure employed in solid-phase processes?
4. What does an arc column consist of?
5. How is heat applied during welding?
6. What is the role of inert atmospheres?
7. What can make a joint brittle while welding?

8. What does the weld metal comprise in arc welding?
9. What is the base metal influenced by?
10. How can residual stress in welded structures be controlled?

3.6 Reading

Characteristics of the Principal Welding Processes

Welding is the process of joining together pieces of metal or metallic parts by bringing them into intimate proximity and heating the places of contact to a state of fusion or plasticity. This leads to interpenetration of the atoms of the metals in the weld zone, and a strong inseparable joint is formed after the metals have cooled.

Welding finds widespread application in almost all branches of industry and construction. Welding is extensively employed in the fabrication and erection of steel structures in industrial construction and civil engineering (frames of industrial buildings, bridges, etc.), vessels of welded-plate construction (steel reservoirs, pipelines, etc.) and concrete reinforcement.

Welding processes may be classified according to the source of energy employed for heating the metals and the state of the metal at the place being welded. A master chart of the principal welding processes is shown on the next page.

In fusion welding the welding area is heated by a concentrated source of heat to a molten state and filler metal must be added to the weld. In accordance with the method applied for feeding the filler metal to the weld, welding procedures are classified as manual, semi-automatic or automatic welding.

Pressure welding processes involve the heating of the metallic parts only to a plastic or lightly fused state and forcing them together with external pressure. Pressure welding processes are applied to metals which are capable of being brought to a plastic state by heating or due to the action of external forces. It has been established that in this process the most weldable metals prove to be those metals which have higher thermal conductivity. Such metals more rapidly dissipate heat from the weld zone and do not allow an excessively high temperature to be concentrated in a small area (the latter may lead to considerable internal stress).

The quality of the joint obtained in pressure welding depends to a great extent upon the magnitude of the applied pressure and the temperature to which the metal is heated at the moment of welding. The higher this temperature, the less unit pressure will be required to produce the weld. Proper cleaning of the surface to be joined is one of the main conditions for obtaining high-quality welds in pressure-welding procedures.

3.7 After-reading activity

Find equivalents in the text for the following word combinations:

Welding is widely used, welded area, disperse heat, parts made of steel, designing and producing metal structures, pressing together.

Use the information of the Master Chart of welding processes above to complete the following sentences:

1. The two basic welding processes are ... .
2. The fusion processes consist of … .
3. Among these, arc welding can be accomplished …
4. Arc welding with consumable electrodes includes the following types…
5. Carbon arc welding, atomic hydrogen welding, inert gas tungsten arc welding refer to … .
6. The pressure processes include … .
7. Resistance welding is divided into three types … .

3.8 Lead-in

Remember all the welding types which you have read about before and make a complete list of these types.

Think and say: What can be the difference between the principle (“traditional”) and alternative types of welding? Why are traditional welding processes not sufficient?

3.9 Reading

Alternative Types of Welding

Cold welding

Cold welding, the joining of materials without the use of heat, can be accomplished simply by pressing them together. Surfaces have to be well prepared, and pressure sufficient to produce 35 to 90 percent deformation at the joint is necessary, depending on the material. Lapped joints in sheets and cold-butt welding of wires constitute the major applications of this technique. Pressure can be applied by punch presses, rolling stands, or pneumatic tooling. Pressures of 1,400,000 to 2,800,000 kilopascals (200,000 to 400,000 pounds per square inch) are needed to produce a joint in aluminum; almost all other metals need higher pressures.

Friction welding

In friction welding two work pieces are brought together under load with one part rapidly revolving. Frictional heat is developed at the interface until the material becomes plastic, at which time the rotation is stopped and the load is increased to consolidate the joint. A strong joint results with the plastic deformation, and in this sense the process may be considered a variation of pressure welding. The process is self-regulating, for, as the temperature at the joint rises, the friction coefficient is reduced and overheating cannot occur. The machines are almost like lathes in appearance. Speed, force, and time are the main variables. The process has been automated for the production of axle casings in the automotive industry.

Laser welding

Laser welding is accomplished when the light energy emitted from a laser source focused upon a workpiece to fuse materials together. The limited availability of lasers of sufficient power for most welding purposes has so far restricted its use in this area. Another difficulty is that the speed and the thickness that can be welded are controlled not so much by power but by the thermal conductivity of the metals and by the avoidance of metal vaporization at the surface. Particular applications of the process with very thin materials up to 0.5 mm (0.02 inch) have, however, been very successful. The process is useful in the joining of miniaturized electrical circuitry.

Diffusion bonding

This type of bonding relies on the effect of applied pressure at an elevated temperature for an appreciable period of time. Generally, the pressure applied must be less than that necessary to cause 5 percent deformation so that the process can be applied to finished machine parts. The process has been used most extensively in the aerospace industries for joining materials and shapes that otherwise could not be made—for example, multiple-finned channels and honeycomb construction. Steel can be diffusion bonded at above 1,000° C (1,800° F) in a few minutes.

Ultrasonic welding

Ultrasonic joining is achieved by clamping the two pieces to be welded between an anvil and a vibrating probe or sonotrode. The vibration raises the temperature at the interface and produces the weld. The main variables are the clamping force, power input, and welding time. A weld can be made in 0.005 second on thin wires and up to 1 second with material 1.3 mm (0.05 inch) thick. Spot welds and continuous seam welds are made with good reliability. Applications include extensive use on lead bonding to integrated circuitry, transistor canning, and aluminum can bodies.

Explosive welding

Explosive welding takes place when two plates are impacted together under an explosive force at high velocity. The lower plate is laid on a firm surface, such as a heavier steel plate. The upper plate is placed carefully at an angle of approximately 5° to the lower plate with a sheet of explosive material on top. The charge is detonated from the hinge of the two plates, and a weld takes place in microseconds by very rapid plastic deformation of the material at the interface. A completed weld has the appearance of waves at the joint caused by a jetting action of metal between the plates.

3.10 After-reading activity

Match a welding type with its description

1. Cold welding	A. Light energy is used to weld parts together.
2. Friction welding	B. The weld is formed at the expense of the applied pressure at a high temperature for a long period of time.

3. Laser welding	C. Vibration is used to generate heat necessary to produce a weld. e
4. Diffusion bonding	D. The heat to accomplish the joint is generated by rotation.
5. Ultrasonic welding	E. The most important factor to accomplish the weld is pressure. No heat is applied.
6. Explosive welding	F. Rapid plastic deformation of the welded materials is caused by detonation.

Fill in the blanks with the right words (namely, types of welding) from the list below:

1. …welding is successfully used in manufacture of small elements of electric circuits.
2. Heat is not used in … welding.
3. … is widely used in aerospace industries.
4. Vibration is used in …welding.
5. Plastic deformation is the basic principle in … welding.
6. … welding is impossible without pressure and high temperature.
7. In … welding one of the parts being welded revolves.

3.11 Writing

Make a summary of alternative welding processes indicating their application capabilities. Start like this:

1. Cold welding that is welding without heat makes it possible to join thin sheets of aluminum.
2. Friction welding…

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Додатки

Додаток А - Welding theory and application definitions

ACETONE:
A flammable, volatile liquid used in acetylene cylinders to dissolve and stabilize acetylene under high pressure.

ACETYLENE:
A highly combustible gas composed of carbon and hydrogen. Used as a fuel gas in the oxyacetylene welding process.

ACTUAL THROAT:
See THROAT OF FILLET WELD.

AIR-ACETYLENE:
A low temperature flare produced by burning acetylene with air instead of oxygen.

AIR-ARC CUTTING:
An arc cutting process in which metals to be cut are melted by the heat of the carbon arc.

ALLOY:
A mixture with metallic properties composed of two or more elements, of which at least one is a metal.

ALTERNATING CURRENT:
An electric current that reverses its direction at regularly recurring intervals.

AMMETER:
An instrument for measuring electrical current in amperes by an indicator activated by the movement of a coil in a magnetic field or by the longitudinal expansion of a wire carrying the current.

ANNEALING:
A comprehensive term used to describe the heating and cooling cycle of steel in the solid state. The term annealing usually implies relatively slow cooling. In annealing, the temperature of the operation, the rate of heating and cooling, and the time the metal is held at heat depend upon the composition, shape, and size of the steel product being treated, and the purpose of the treatment. The more important purposes for which steel is annealed are as follows: to remove stresses; to induce softness; to alter ductility, toughness, electric, magnetic, or other physical and mechanical properties; to change the crystalline structure; to remove gases; and to produce a definite microstructure.

ARC BLOW:
The deflection of an electric arc from its normal path because of magnetic forces.

ARC BRAZING:

A brazing process wherein the heat is obtained from an electric arc formed between the base metal and an electrode, or between two electrodes.

ARC CUTTING:

A group of cutting processes in which the cutting of metals is accomplished by melting with the heat of an arc between the electrode and the base metal. See CARBON-ARC CUTTING, METAL-ARC CUTTING, ARC-OXYGEN CUTTING, AND AIR-ARC CUTTING.

ARC LENGTH:

The distance between the tip of the electrode and the weld puddle.

ARC-OXYGEN CUTTING:

An oxygen-cutting process used to sever metals by a chemical reaction of oxygen with a base metal at elevated temperatures.

ARC VOLTAGE:

The voltage across the welding arc.

ARC WELDING:

A group of welding processes in which fusion is obtained by heating with an electric arc or arcs, with or without the use of filler metal.

AS WELDED:

The condition of weld metal, welded joints, and weldments after welding and prior to any subsequent thermal, mechanical, or chemical treatments.

ATOMIC HYDROGEN WELDING:

An arc welding process in which fusion is obtained by heating with an arc maintained between two metal electrodes in an atmosphere of hydrogen. Pressure and/or filler metal may or may not be used.

AUSTENITE:

The non-magnetic form of iron characterized by a face-centered cubic lattice crystal structure. It is produced by heating steel above the upper critical temperature and has a high solid solubility for carbon and alloying elements.

AXIS OF A WELD:

A line through the length of a weld, perpendicular to a cross section at its center of gravity.

BACK FIRE:

The momentary burning back of a flame into the tip, followed by a snap or pop, then immediate reappearance or burning out of the flame.

BACK PASS:

A pass made to deposit a back weld.

BACK UP:

In flash and upset welding, a locator used to transmit all or a portion of the upsetting force to the workpieces.

BACK WELD:

A weld deposited at the back of a single groove weld.

BACKHAND WELDING:

A welding technique in which the flame is directed towards the completed weld.

BACKING STRIP:

A piece of material used to retain molten metal at the root of the weld and/or increase the thermal capacity of the joint so as to prevent excessive warping of the base metal.

BACKING WELD:

A weld bead applied to the root of a single groove joint to assure complete root penetration.

BACKSTEP:

A sequence in which weld bead increments are deposited in a direction opposite to the direction of progress.

BARE ELECTRODE:

An arc welding electrode that has no coating other than that incidental to the drawing of the wire.

BARE METAL-ARC WELDING:

An arc welding process in which fusion is obtained by heating with an unshielded arc between a bare or lightly coated electrode and the work. Pressure is not used and filler metal is obtained from the electrode.

BASE METAL:

The metal to be welded or cut. In alloys, it is the metal present in the largest proportion.

BEAD WELD:

A type of weld composed of one or more string or weave beads deposited on an unbroken surface.

BEADING:

See STRING BEAD WELDING and WEAVE BEAD.

BEVEL ANGLE:

The angle formed between the prepared edge of a member and a plane perpendicular to the surface of the member.

BLACKSMITH WELDING: See

FORGE WELDING.

BLOCK BRAZING:

A brazing process in which bonding is produced by the heat obtained from heated blocks applied to the parts to be joined and by a nonferrous filler metal having a melting point above 800 °F (427 °C), but below that of the base metal. The filler metal is distributed in the joint by capillary attraction.

BLOCK SEQUENCE:

A building up sequence of continuous multipass welds in which separated lengths of the weld are completely or partially built up before intervening lengths are deposited. See BUILDUP SEQUENCE.

BLOW HOLE:
see GAS POCKET.

BOND:
The junction of the welding metal and the base metal.

BOXING:
The operation of continuing a fillet weld around a corner of a member as an extension of the principal weld.

BRAZING:
A group of welding processes in which a groove, fillet, lap, or flange joint is bonded by using a nonferrous filler metal having a melting point above 800 °F (427 °C), but below that of the base metals. Filler metal is distributed in the joint by capillary attraction.

BRAZE WELDING:
A method of welding by using a filler metal that liquefies above 450 °C (842 °F) and below the solid state of the base metals. Unlike brazing, in braze welding, the filler metal is not distributed in the joint by capillary action.

BRIDGING:
A welding defect caused by poor penetration. A void at the root of the weld is spanned by weld metal.

BUCKLING:
Distortion caused by the heat of a welding process.

BUILDUP SEQUENCE:
The order in which the weld beads of a multipass weld are deposited with respect to the cross section of a joint. See BLOCK SEQUENCE.

BUTT JOINT:
A joint between two workpieces in such a manner that the weld joining the parts is between the surface planes of both of the pieces joined.

BUTT WELD:
A weld in a butt joint.

BUTTER WELD:
A weld caused of one or more string or weave beads laid down on an unbroken surface to obtain desired properties or dimensions.

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

CARBIDE PRECIPITATION:
A condition occurring in austenitic stainless steel which contains carbon in a supersaturated solid solution. This condition is unstable. Agitation of the steel during welding causes the excess carbon in solution to precipitate. This effect is also called weld decay.

CARBON-ARC CUTTING:

A process of cutting metals with the heat of an arc between a carbon electrode and the work.

CARBON-ARC WELDING:

A welding process in which fusion is produced by an arc between a carbon electrode and the work. Pressure and/or filler metal and/or shielding may or may not be used.

CARBONIZING FLAME:

An oxyacetylene flame in which there is an excess of acetylene. Also called excess acetylene or reducing flame.

CASCADE SEQUENCE: Subsequent beads are stopped short of a previous bead, giving a cascade effect.

CASE HARDENING:

A process of surface hardening involving a change in the composition of the outer layer of an iron base alloy by inward diffusion from a gas or liquid, followed by appropriate thermal treatment. Typical hardening processes are carbonizing, cyaniding, carbonitriding, and nitriding.

CHAIN INTERMITTENT FILLET WELDS:

Two lines of intermittent fillet welds in a T or lap joint in which the welds in one line are approximately opposite those in the other line.

CHAMFERING:

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

COALESCENCE:

The uniting or fusing of metals upon heating.

COATED ELECTRODE:

An electrode having a flux applied externally by dipping, spraying, painting, or other similar methods. Upon burning, the coat produces a gas which envelopes the arc.

COMMUTORY CONTROLLED WELDING:

The making of a number of spot or projection welds in which several electrodes, in simultaneous contact with the work, progressively function under the control of an electrical commutating device.

COMPOSITE ELECTRODE:

A filler metal electrode used in arc welding, consisting of more than one metal component combined mechanically. It may or may not include materials that improve the properties of the weld, or stabilize the arc.

COMPOSITE JOINT:

A joint in which both a thermal and mechanical process are used to unite the base metal parts.

CONCAVITY:

The maximum perpendicular distance from the face of a concave weld to a line joining the toes.

CONCURRENT HEATING:
Supplemental heat applied to a structure during the course of welding.
CONE:
The conical part of a gas flame next to the orifice of the tip.
CONSUMABLE INSERT:
Preplaced filler metal which is completely fused into the root of the joint and becomes part of the weld.
CONVEXITY:
The maximum perpendicular distance from the face of a convex fillet weld to a line joining the toes.
CORNER JOINT:
A joint between two members located approximately at right angles to each other in the form of an L.
COVER GLASS:
A clear glass used in goggles, hand shields, and helmets to protect the filter glass from spattering material.
COVERED ELECTRODE:
A metal electrode with a covering material which stabilizes the arc and improves the properties of the welding metal. The material may be an external wrapping of paper, asbestos, and other materials or a flux covering.
CRACK:
A fracture type discontinuity characterized by a sharp tip and high ratio of length and width to opening displacement.
CRATER:
A depression at the termination of an arc weld.
CRITICAL TEMPERATURE:
The transition temperature of a substance from one crystalline form to another.
CURRENT DENSITY:
Amperes per square inch of the electrode cross sectional area.
CUTTING TIP:
A gas torch tip especially adapted for cutting.
CUTTING TORCH:
A device used in gas cutting for controlling the gases used for preheating and the oxygen used for cutting the metal.
CYLINDER:
A portable cylindrical container used for the storage of a compressed gas.
DEFECT:
A discontinuity or discontinuities which, by nature or accumulated effect (for example, total crack length), render a part or product unable to meet the minimum applicable acceptance standards or specifications. This term designates rejectability.
DEPOSITED METAL:
Filler metal that has been added during a welding operation.

DEPOSITION EFFICIENCY:

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

DEPTH OF FUSION:

The distance from the original surface of the base metal to that point at which fusion ceases in a welding operation.

DIE:

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

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

DIE WELDING:

A forge welding process in which fusion is produced by heating in a furnace and by applying pressure by means of dies.

DIP BRAZING:

A brazing process in which bonding is produced by heating in a molten chemical or metal bath and by using a nonferrous filler metal having a melting point above 800 °F (427 °C), but below that of the base metals. The filler metal is distributed in the joint by capillary attraction. When a metal bath is used, the bath provides the filler metal.

DIRECT CURRENT ELECTRODE NEGATIVE (DCEN):

The arrangement of direct current arc welding leads in which the work is the positive pole and the electrode is the negative pole of the welding arc.

DIRECT CURRENT ELECTRODE POSITIVE (DCEP):

The arrangement of direct current arc welding leads in which the work is the negative pole and the electrode is the positive pole of the welding arc.

DISCONTINUITY:

An interruption of the typical structure of a weldment, such as lack of homogeneity in the mechanical, metallurgical, or physical characteristics of the material or weldment. A discontinuity is not necessarily a defect.

DRAG:

The horizontal distance between the point of entrance and the point of exit of a cutting oxygen stream.

DUCTILITY:

The property of a metal which allows it to be permanently deformed, in tension, before final rupture. Ductility is commonly evaluated by tensile testing in which the amount of elongation and the reduction of area of the broken specimen, as compared to the original test specimen, are measured and calculated.

DUTY CYCLE:

The percentage of time during an arbitrary test period, usually 10 minutes, during which a power supply can be operated at its rated output without overloading.

EDGE JOINT:

A joint between the edges of two or more parallel or nearly parallel members.

EDGE PREPARATION:

The contour prepared on the edge of a joint member for welding.

EFFECTIVE LENGTH OF WELD:

The length of weld throughout which the correctly proportioned cross section exits.

ELECTRODE:

a. Metal-Arc. Filler metal in the form of a wire or rod, whether bare or covered, through which current is conducted between the electrode holder and the arc.

b. Carbon-Arc. A carbon or graphite rod through which current is conducted between the electrode holder and the arc.

c. Atomic . One of the two tungsten rods between the points of which the arc is maintained.

d. Electrolytic Oxygen-Hydrogen Generation. The conductors by which current enters and leaves the water, which is decomposed by the passage of the current.

e. Resistance Welding. The part or parts of a resistance welding machine through which the welding current and the pressure are applied directly to the work.

ELECTRODE FORCE:

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

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

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

ELECTRODE HOLDER:

A device used for mechanically holding the electrode and conduct- ing current to it.

ELECTRODE SKID:

The sliding of an electrode along the surface of the work during spot, seam, or projection welding.

EMBOSSMENT:

A rise or protrusion from the surface of a metal.

ETCHING:
A process of preparing metallic specimens and welds for macrographic or micrographic examination.

FACE REINFORCEMENT:
Reinforcement of weld at the side of the joint from which welding was done.

FACE OF WELD:
The exposed surface of a weld, made by an arc or gas welding process, on the side from which welding was done.

FAYING SURFACE:
That surface of a member that is in contact with another member to which it is joined.

FERRITE:
The virtually pure form of iron existing below the lower critical temperature and characterized by a body-centered cubic lattice crystal structure. It is magnetic and has very slight solid solubility for carbon.

FILLER METAL:
Metal to be added in making a weld.

FILLET WELD:
A weld of approximately triangular cross section, as used in a lap joint, joining two surfaces at approximately right angles to each other.

FILTER GLASS:
A colored glass used in goggles, helmets, and shields to exclude harmful light rays.

FLAME CUTTING:
see OXYGEN CUTTING.

FLAME GOUGING:
See OXYGEN GOUGING.

FLAME HARDENING:
A method for hardening a steel surface by heating with a gas flame followed by a rapid quench.

FLAME SOFTENING:
A method for softening steel by heating with a gas flame followed by slow cooling.

FLASH:
Metal and oxide expelled from a joint made by a resistance welding process.

FLASH WELDING:
A resistance welding process in which fusion is produced, simultaneously over the entire area of abutting surfaces, by the heat obtained from resistance to the flow of current between two surfaces and by the application of pressure after heating is substantially completed. Flashing is accompanied by expulsion of metal from the joint.

FLASHBACK:

The burning of gases within the torch or beyond the torch in the hose, usually with a shrill, hissing sound.

FLAT POSITION:

The position in which welding is performed from the upper side of the joint and the face of the weld is approximately horizontal.

FILM BRAZING:

A process in which bonding is produced by heating with a molten nonferrous filler metal poured over the joint until the brazing temperature is attained. The filler metal is distributed in the joint by capillary attraction. See BRAZING.

FLOW WELDING:

A process in which fusion is produced by heating with molten filler metal poured over the surfaces to be welded until the welding temperature is attained and the required filler metal has been added. The filler metal is not distributed in the joint by capillary attraction.

FLUX:

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

FOREHAND WELDING:

A gas welding technique in which the flare is directed against the base metal ahead of the completed weld.

FORGE WELDING:

A group of welding processes in which fusion is produced by heating in a forge or furnace and applying pressure or blows.

FREE BEND TEST:

A method of testing weld specimens without the use of a guide.

FULL FILLET WELD:

A fillet weld whose size is equal to the thickness of the thinner member joined.

FURNACE BRAZING:

A process in which bonding is produced by the furnace heat and a nonferrous filler metal having a melting point above 800 °F (427 °C), but below that of the base metals. The filler metal is distributed in the joint by capillary attraction.

FUSION:

A thorough and complete mixing between the two edges of the base metal to be joined or between the base metal and the filler metal added during welding.

FUSION ZONE (FILLER PENETRATION):

The area of base metal melted as determined on the cross section of a weld.

GAS CARBON-ARC WELDING:

An arc welding process in which fusion is produced by heating with an electric arc between a carbon electrode and the work. Shielding is obtained from an inert gas such as helium or argon. Pressure and/or filler metal may or may not be used.

GAS METAL-ARC (MIG) WELDING (GMAW):

An arc welding process in which fusion is produced by heating with an electric arc between a metal electrode and the work. Shielding is obtained from an inert gas such as helium or argon. Pressure and/or filler metal may or my not be used.

GAS POCKET:

A weld cavity caused by the trapping of gases released by the metal when cooling.

GAS TUNGSTEN-ARC (TIG) WELDING (GTAW):

An arc welding process in which fusion is produced by heating with an electric arc between a tungsten electrode and the work while an inert gas forms around the weld area to prevent oxidation. No flux is used.

GAS WELDING:

A process in which the welding heat is obtained from a gas flame.

GLOBULAR TRANSFER (ARC WELDING):

A type of metal transfer in which molten filler metal is transferred across the arc in large droplets.

GOGGLES:

A device with colored lenses which protect the eyes from harmful radiation during welding and cutting operations.

GROOVE:

The opening provided between two members to be joined by a groove weld.

GROOVE ANGLE:

The total included angle of the groove between parts to be joined by a groove weld.

GROOVE FACE:

That surface of a member included in the groove.

GROOVE RADIUS:

The radius of a J or U groove.

GROOVE WELD:

A weld made by depositing filler metal in a groove between two members to be joined.

GROUND CONNECTION:

The connection of the work lead to the work.

GROUND LEAD:

See WORK LEAD.

GUIDED BEND TEST:

A bending test in which the test specimen is bent to a definite shape by means of a jig.

HAMMER WELDING:

A forge welding process.

HAND SHIELD:

A device used in arc welding to protect the face and neck. It is equipped with a filter glass lens and is designed to be held by hand.

HARD FACING:

A particular form of surfacing in which a coating or cladding is applied to a surface for the main purpose of reducing wear or loss of material by abrasion, impact, erosion, galling, and cavitations.

HARD SURFACING:

The application of a hard, wear-resistant alloy to the surface of a softer metal.

HARDENING:

a. The heating and quenching of certain iron-base alloys from a temperature above the critical temperature range for the purpose of producing a hardness superior to that obtained when the alloy is not quenched. This term is usually restricted to the formation of martensite.

b. Any process of increasing the hardness of metal by suitable treatment, usually involving heating and cooling.

HEAT AFFECTED ZONE:

That portion of the base metal whose structure or properties have been changed by the heat of welding or cutting.

HEAT TIME:

The duration of each current impulse in pulse welding.

HEAT TREATMENT:

An operation or combination of operations involving the heating and cooling of a metal or an alloy in the solid state for the purpose of obtaining certain desirable conditions or properties. Heating and cooling for the sole purpose of mechanical working are excluded from the meaning of the definition.

HEATING GATE:

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

HELMET:

A device used in arc welding to protect the face and neck. It is equipped with a filter glass and is designed to be worn on the head.

HOLD TIME:

The time that pressure is maintained at the electrodes after the welding current has stopped.

HORIZONTAL WELD:

A bead or butt welding process with its linear direction horizontal or inclined at an angle less than 45 degrees to the horizontal, and the parts welded being vertically or approximately vertically disposed.

HORN:

The electrode holding arm of a resistance spot welding machine.

HORN SPACING:

In a resistance welding machine, the unobstructed work clearance between horns or platens at right angles to the throat depth. This distance is measured with the horns parallel and horizontal at the end of the downstroke.

HOT SHORT:

A condition which occurs when a metal is heated to that point, prior to melting, where all strength is lost but the shape is still maintained.

HYDROGEN BRAZING:

A method of furnace brazing in a hydrogen atmosphere.

HYDROMATIC WELDING:

See PRESSURE CONTROLLED WELDING.

HYGROSCOPIC:

Readily absorbing and retaining moisture.

IMPACT TEST:

A test in which one or more blows are suddenly applied to a specimen. The results are usually expressed in terms of energy absorbed or number of blows of a given intensity required to break the specimen.

IMPREGNATED-TAPE METAL-ARC WELDING

An arc welding process in which fusion is produced by heating with an electric arc between a metal electrode and the work. Shielding is obtained from decomposition of impregnated tape wrapped around the electrode as it is fed to the arc. Pressure is not used, and filler metal is obtained from the electrode.

INDUCTION BRAZING:

A process in which bonding is produced by the heat obtained from the resistance of the work to the flow of induced electric current and by using a nonferrous filler metal having a melting point above 800 °F (427 °C), but below that of the base metals. The filler metal is distributed in the joint by capillary attraction.

INDUCTION WELDING:

A process in which fusion is produced by heat obtained from resistance of the work to the flow of induced electric current, with or without the application of pressure.

INERT GAS:

A gas which does not normally combine chemically with the base metal or filler metal.

INTERPASS TEMPERATURE:

In a multipass weld, the lowest temperature of the deposited weld meal before the next pass is started.

JOINT:

The portion of a structure in which separate base metal parts are joined.

JOINT PENETRATION:

The maximum depth a groove weld extends from its face into a joint, exclusive of reinforcement.

KERF:

The space from which metal has been removed by a cutting process.

LAP JOINT:

A joint between two overlapping members.

LAYER:

A stratum of weld metal, consisting of one or more weld beads.

LEG OF A FILLET WELD:

The distance from the root of the joint to the toe of the fillet weld.

LIQUIDUS:

The lowest temperature at which a metal or an alloy is completely liquid.

LOCAL PREHEATING:

Preheating a specific portion of a structure.

LOCAL STRESS RELIEVING:

Stress relieving heat treatment of a specific portion of a structure.

MANIFOLD:

A multiple header for connecting several cylinders to one or more torch supply lines.

MARTENSITE:

Martensite is a microconstituent or structure in quenched steel characterized by an acicular or needle-like pattern on the surface of polish. It has the maximum hardness of any of the structures resulting from the decomposition products of austenite.

MASH SEAM WELDING:

A seam weld made in a lap joint in which the thickness at the lap is reduced to approximately the thickness of one of the lapped joints by applying pressure while the metal is in a plastic state.

MELTING POINT:

The temperature at which a metal begins to liquefy.

MELTING RANGE:

The temperature range between solidus and liquidus.

MELTING RATE:

The weight or length of electrode melted in a unit of time.

METAL-ARC CUTTING:

The process of cutting metals by melting with the heat of the metal arc.

METAL-ARC WELDING:

An arc welding process in which a metal electrode is held so that the heat of the arc fuses both the electrode and the work to form a weld.

METALLIZING:

A method of overlay or metal bonding to repair worn parts.

MIXING CHAMBER:

That part of a welding or cutting torch in which the gases are mixed for combustion.

MULTI-IMPULSE WELDING:

The making of spot, projection, and upset welds by more than one impulse of current. When alternating current is used each impulse may consist of a fraction of a cycle or a number of cycles.

NEUTRAL FLAME:

A gas flame in which the oxygen and acetylene volumes are balanced and both gases are completely burned.

NICK BREAK TEST:

A method for testing the soundness of welds by nicking each end of the weld, then giving the test specimen a sharp hammer blow to break the weld from nick to nick. Visual inspection will show any weld defects.

NONFERROUS:

Metals which contain no iron. Aluminum, brass, bronze, copper, lead, nickel, and titanium are nonferrous.

NORMALIZING:

Heating iron-base alloys to approximately 100 °F (38 °C) above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.

NUGGET:

The fused metal zone of a resistance weld.

OPEN CIRCUIT VOLTAGE:

The voltage between the terminals of the welding source when no current is flowing in the welding circuit.

OVERHEAD POSITION:

The position in which welding is performed from the underside of a joint and the face of the weld is approximately horizontal.

OVERLAP:

The protrusion of weld metal beyond the bond at the toe of the weld.

OXIDIZING FLAME:

An oxyacetylene flame in which there is an excess of oxygen. The unburned excess tends to oxidize the weld metal.

OXYACETYLENE CUTTING:

An oxygen cutting process in which the necessary cutting temperature is maintained by flames obtained from the combustion of acetylene with oxygen.

OXYACETYLENE WELDING:

A welding process in which the required temperature is attained by flames obtained from the combustion of acetylene with oxygen.

OXY-ARC CUTTING:

An oxygen cutting process in which the necessary cutting temperature is maintained by means of an arc between an electrode and the base metal.

OXY-CITY GAS CUTTING:

An oxygen cutting process in which the necessary cutting temperature is maintained by flames obtained from the combustion of city gas with oxygen.

OXYGEN CUTTING:

A process of cutting ferrous metals by means of the chemical action of oxygen on elements in the base metal at elevated temperatures.

OXYGEN GOUGING:

An application of oxygen cutting in which a chamfer or groove is formed.

OXY-HYDROGEN CUTTING:

An oxygen cutting process in which the necessary cutting temperature is maintained by flames obtained from the combustion of city gas with oxygen.

OXY-HYDROGEN WELDING:

A gas welding process in which the required welding temperature is attained by flames obtained from the combustion of hydrogen with oxygen.

OXY-NATURAL GAS CUTTING:

An oxygen cutting process in which the necessary cutting temperature is maintained by flames obtained by the combustion of natural gas with oxygen.

OXY-PROPANE CUTTING:

An oxygen cutting process in which the necessary cutting temperature is maintained by flames obtained from the combustion of propane with oxygen.

PASS:

The weld metal deposited in one general progression along the axis of the weld.

PEENING:

The mechanical working of metals by means of hammer blows. Peening tends to stretch the surface of the cold metal, thereby relieving contraction stresses.

PENETRANT INSPECTION:

a. Fluorescent. A water washable penetrant with high fluorescence and low surface tension. It is drawn into small surface openings by capillary action. When exposed to black light, the dye will fluoresce.

b. Dye. A process which involves the use of three noncorrosive liquids. First, the surface cleaner solution is used. Then the penetrant is applied and allowed to stand at least 5 minutes. After standing, the penetrant is removed with the leaner solution and the developer is applied. The dye penetrant, which has remained in the surface discontinuity, will be drawn to the surface by the developer resulting in bright red indications.

PERCUSSIVE WELDING:

A resistance welding process in which a discharge of electrical energy and the application of high pressure occurs simultaneously, or with the electrical discharge occurring slightly before the application of pressure.

PERLITE:

Perlite is the lamellar aggregate of ferrite and iron carbide resulting from the direct transformation of austenite at the lower critical point.

PITCH:

Center to center spacing of welds.

PLUG WELD:

A weld is made in a hole in one member of a lap joint, joining that member to that portion of the surface of the other member which is exposed through the hole. The walls of the hole may or may not be parallel, and the hole may be partially or completely filled with the weld metal.

TRANSVERSE SEAM WELDING:

The making of a seam weld in a direction essentially at right angles to the throat depth of a seam welding machine.

TUNGSTEN ELECTRODE:

A non-filler metal electrode used in arc welding or cutting, made principally of tungsten.

UNDERBEAD CRACK:

A crack in the heat affected zone not extending to the surface of the base metal.

UNDERCUT:

A groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal.

UNDERCUTTING:

An undesirable crater at the edge of the weld caused by poor weaving technique or excessive welding speed.

UPSET:

A localized increase in volume in the region of a weld, resulting from the application of pressure.

UPSET WELDING:

A resistance welding process in which fusion is produced simultaneously over the entire area of abutting surfaces, or progressively along a joint, by the heat obtained from resistance to the flow of electric current through the area of contact of those surfaces. Pressure is applied before heating is started and is maintained throughout the heating period.

UPSETTING FORCE:

The force exerted at the welding surfaces in flash or upset welding.

VERTICAL POSITION:

The position of welding in which the axis of the weld is approximately vertical. In pipe welding, the pipe is in a vertical position and the welding is done in a horizontal position.

WANDERING BLOCK SEQUENCE:

A block welding sequence in which successive weld blocks are completed at random after several starting blocks have been completed.

WANDERING SEQUENCE:

A longitudinal sequence in which the weld bead increments are deposited at random.

WAX PATTERN:

Wax molded around the parts to be welded by a thermit welding process to the form desired for the completed weld.

WEAVE BEAD:

A type of weld bead made with transverse oscillation.

WEAVING:

A technique of depositing weld metal in which the electrode is oscillated. It is usually accomplished by a semicircular motion of the arc to the right and left of the direction of welding. Weaving serves to increase the width of the deposit, decreases overlap, and assists in slag formation.

WELD:

A localized fusion of metals produced by heating to suitable temperatures. Pressure and/or filler metal may or may not be used. The filler material has a melting point approximately the same or below that of the base metals, but always above 800 °F (427 °C).

WELD BEAD:

A weld deposit resulting from a pass.

WELD GAUGE:

A device designed for checking the shape and size of welds.

WELD METAL:

That portion of a weld that has been melted during welding.

WELD SYMBOL:

A picture used to indicate the desired type of weld.

WELDABILITY:

The capacity of a material to form a strong bond of adherence under pressure or when solidifying from a liquid.

WELDER CERTIFICATION:

Certification in writing that a welder has produced welds meeting prescribed standards.

WELDER PERFORMANCE QUALIFICATION:

The demonstration of a welder's ability to produce welds meeting prescribed standards.

WELDING LEADS:

a. Electrode lead. The electrical conductor between the source of the arc welding current and the electrode holder.

b. Work lead. The electrical conductor between the source of the arc welding current and the workpiece.

WELDING PRESSURE:

The pressure exerted during the welding operation on the parts being welded.

WELDING PROCEDURE:

The detailed methods and practices including all joint welding procedures involved in the production of a weldment.

WELDING ROD:

Filler metal in wire or rod form, used in gas welding and brazing processes and in those arc welding processes in which the electrode does not provide the filler metal.

WELDING SYMBOL:

The assembled symbol consists of the following eight elements, or such of these as are necessary: reference line, arrow, basic weld symbols, dimension and other data, supplementary symbols, finish symbols, tail, specification, process, or other references.

WELDING TECHNIQUE:

The details of a manual, machine, or semiautomatic welding operation which, within the limitations of the prescribed joint welding procedure, are controlled by the welder or welding operator.

WELDING TIP:

The tip of a gas torch especially adapted to welding.

WELDING TORCH:

A device used in gas welding and torch brazing for mixing and controlling the flow of gases.

WELDING TRANSFORMER:

A device for providing current of the desired voltage.

WELDMENT:

An assembly whose component parts are formed by welding.

WIRE FEED SPEED:

The rate of speed in mm/sec or in./min at which a filler metal is consumed in arc welding or thermal spraying.

WORK LEAD:

The electric conductor (cable) between the source of arc welding current and the workpiece.

X-RAY:

A radiographic test method used to detect internal defects in a weld.