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Employment Opportunities For Welders

Bulletin No. 844

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Letter of Transmittal

UNITED STATES DEPARTMENT OF LABOR,
BUREAU OF LABOR STATISTICS,
Washington, D. C., September 18, 1945.

The SECRETARY OF LABOR:

I have the honor to transmit herewith a report on employment opportunities for welders. This is one of a series of occupational studies prepared in the Bureau's Occupational Outlook Division for use in vocational counseling of veterans, young people in schools, and others considering the choice of an occupation. This study was prepared by Richard H. Lewis with the assistance of Calman R. Winegarden.

A. F. HINRICHS, *Acting Commissioner.*

HON. L. B. SCHWELLENBACH,
Secretary of Labor.

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Employment Opportunities for Welders

Summary

The employment outlook for welders is less favorable than for many other metalworking occupations, and is especially unfavorable for persons without broad welding training or experience. This is the chief conclusion of an analysis of the job prospects for welders made by the Bureau of Labor Statistics to provide information for vocational guidance of veterans, high-school students, and workers released from war production. An immediate postwar drop in the number of welding jobs is indicated, despite the evidence of increasing use of welding in many industries. This decline will be caused mainly by the sharp cuts expected in welding employment in shipbuilding and other war industries.

Hand welders, in general the most skilled, will be more severely affected than machine welders. Among hand welders, the demand for fully qualified all-round workers should hold up better than for those with less skill. A factor depressing the long-run job outlook for welders is the development of improved equipment which increases productivity and reduces the degree of skill required. Local repair and job shops present an opportunity for some skilled welders to enter business for themselves. The demand for welders to replace those who leave the occupation through death or retirement is likely to be low for many years because of the relative youth of most of the welding labor force.

Welding, although a fairly new occupation, was important even before the war, with 125,000 welders and flame-cutters employed in 1940. A spectacular increase in welding employment occurred during the war, mainly because of the large requirements for welders in shipyards. Welders were also important in the production of aircraft and ordnance. The peak wartime employment of welders and flame-cutters is estimated at 364,000.

Welders are used in many industries in maintenance work, but the greatest possibilities for expansion of employment occur in production work. The principal peacetime industries employing welders were automobiles, iron and steel industries, machinery industries, electrical equipment, and local repair services. Although all these industries are expected to employ large numbers of welders in the postwar period, and in many cases provide more welding jobs than they did before the war, this employment will not be large enough to offset the loss of welding jobs in war industries. This reduction in jobs is the more serious when related to the large numbers who have acquired welding training and experience during the war.

Women workers held few welding jobs before the war, but during the war their number increased to at least 15 percent of the total welding employment. Women are well adapted to the physical demands of welding, and the large wartime needs for welders combined with the manpower shortage to open up many types of welding jobs to them, particularly in shipbuilding.

There are job opportunities for welders in every State in the country. Before the war, large proportions of the welders were employed in Middle Western States. During the war there has been a shift in importance toward the coastal States, where shipyards and many aircraft plants are situated. The Middle West should again have the largest percentage of the welding jobs in the immediate postwar period, although the actual number of jobs there may be no higher than it was during the war.

The training of welders is mainly confined to hand welders. About 200 hours of instruction in welding theory and practice are considered enough to train a welder to do competent production work, but a period of work experience is required to become an all-round welder.

The wages of hand welders approximate those of many skilled machine operators. During the war their straight-time hourly earnings have generally averaged above $1 an hour.

Several types of hazards are peculiar to welding work, but proper safety precautions can adequately protect against them. The nature of the working conditions of welders depends greatly upon the industry in which they are employed.

Nature and Importance of the Occupation

To many people, welding has been a symbol of the "war job," representing the typical war-production occupation as distinguished from the normal peacetime vocations. The growing importance of welding in shipbuilding and in aircraft and ordnance manufacture has been the basis for the current widespread vocational interest in welding. Popular interest has been stimulated by the dramatic appearance of the welder, with his bizarre helmet, as he guides the dazzling electric arc along the weld amid a shower of sparks. Welding, however, constituted an important occupation before the war, although it is of comparatively recent origin. The Census of Population reported 125,000 welders and flame-cutters employed in March 1940. This number has been multiplied during the war in response to the requirements of war production.

Welding can only very loosely be considered as a single occupation. Welding processes vary considerably and even for the same method, the welders, or welding operators, as they are frequently termed, may differ in skill and responsibility. In general, welding may be defined as the joining of metal parts while the edges are in a molten or plastic state. This fusion is accomplished through the application of heat, and in some types of welding, mechanical pressure is used simultaneously to force the edges together. Additional metal is often introduced into the weld. A characteristic of welding is that the parts joined actually become fused into one, in many cases actually being stronger at the joint, while in the similar fabricating processes of soldering and brazing the metal parts are attached by using such metals as silver or bronze to bond the edges together without actual fusion occurring.

Oxyacetylene gas welding, the oldest type of welding now in common use, utilizes a direct flame produced by the combustion of acetylene gas with oxygen to make molten the edges of the material joined. Electric-arc welding, the method most frequently used, produces fusion through the intense heat resulting when an electric arc passes a short distance through the air between the material being welded and an electrode manipulated by the welding operator.

Electric-resistance welding is quite a different operation from the two other important types of welding, although its purpose is the same. In this method the heat which causes fusion is produced by resistance to an electric current sent through the materials to be welded. The more important types of resistance welding are spot, butt, flash, and seam welding.

Besides the three most important methods, several other special types of welding are in use. Thermit welding is used mainly for repairing large units made of iron and steel, such as locomotive frames, heavy crank shafts, and railroad rails. A molten steel is produced by melting aluminum powder and iron oxide together in a crucible and pouring the resulting liquid steel around the section to be welded, which has been preheated to protect against the intense heat of the molten steel. Atomic-hydrogen welding and helium-arc welding are two variations of arc welding which are finding increasing application, the helium-arc method being used particularly in the welding of aluminum and magnesium.

The techniques of both methods of hand welding, or manual welding as it is technically called, are similar in many respects. The electric-arc welder touches the welding rod (electrode) to the metal to be welded, completing an electric circuit, and then withdraws it a short distance, causing an electric arc to pass through the intervening space. He then makes the weld by guiding the arc, with its intense heat, along the edges to be joined, usually with metal from the electrode flowing into the weld. The distance the electrode is held from the metal surface and the speed of movement largely determine the nature of the weld.

The principal difference in the oxyacetylene method is that the operator directs upon the weld a flame resulting from the combustion of the two gases in the welding torch. The welder must know how to regulate the flame and adjust the valves which control the mixing of the gases. Additional metal is introduced into the weld from a metal rod held in the welder's other hand.

The skill required for a hand-welding job depends primarily on the scope of the welder's duties. Some jobs involve only the performance of very repetitive operations, which can be learned in a relatively short time. In other cases the welders may be required to have all-round metal-fabricating knowledge. Welding is often regarded by employers as a tool to be applied by skilled metalworkers, rather than as a separate occupational specialty. A fully qualified welder must be able to read blueprints, understand welding symbols, plan the work, and set it up in jigs or other work-holding devices, in addition to being expert in all phases of the actual welding techniques.

The occupation of oxyacetylene burner or flame-cutter is related to oxyacetylene welding, the difference being that the torch is used to cut metal rather than weld. Experience in burning may often serve as partial preparation for a gas-welding job.

The operators of resistance-welding machines are commonly called welders and are classified as such by the Census of Population, but their duties bear little relationship to those of arc or gas welders. Possible opportunities in resistance machine welding are less significant from the viewpoint of vocational guidance. The nature of the machine welder's job depends upon the particular type of equipment, with none of the manipulative skills of arc and gas welding being required, and generalized preemployment training is neither necessary nor possible.

The development and increasing use of automatic arc-welding machines may have a significant effect on employment opportunities for hand welders. The operators of these automatic machines constitute an occupational specialty distinct from manual arc and gas welders and from resistance machine welders, and one that may tend to displace hand welders for many welding applications.

Trends in Prewar Use of Welding

Welding in its modern forms is a comparatively recent development. The method termed "forge welding" dates back many centuries but has been almost entirely superseded by more satisfactory techniques. The most commonly applied types of welding—electric-arc, gas, and electric-resistance—were originated in the 1880's and 1890's and had a slow development until World War I. Progress in welding was stimulated during the war period by its application to several types of ordnance production and to some extent in shipbuilding. It was also used extensively in ship-salvaging operations. For a while after the first World War, welding was used principally as a maintenance tool and for such specialized purposes as pipe-line construction. About 1929 welding began to be applied more widely and intensively in production processes. An indication of the growth in the volume of welding after 1929 is the steady increase in sales of electrodes for arc welding during the 1930's, shown in the Census of Manufactures: the production of arc-welding electrodes, which had been reported at $1,259,000 in 1929, climbed to $2,598,000 in 1931, $5,379,000 in 1935 and to a peak of $9,888,000 in 1937. In terms of weight of electrodes produced, the increase was even more striking, the total rising from 15,827,643 in pounds in 1931 to 198,995,000 in 1940.[1]

The greatly increased acceptance of welding as a production process indicated by this trend resulted from several factors. Continual technical progress had been made in welding equipment and accessories, as well as in new applications or techniques. One of the hindrances to widespread acceptance had been the doubt felt by many as to the strength and safety of welds. That attitude was partly attributable to difficulties experienced in inspecting and testing welds. Progress was made in creating equipment and new methods (X-ray and Magniflux, for example) to inspect and test the soundness of welds. The use of welding was also stimulated as production engineers and others began to realize the efficiency and economy of welding for many types of fabrication. Units joined by welding are often lighter and stronger than when other methods of joining are used. Substitution of welding for riveting saves the

[1] The Welding Engineer (Chicago), March 1944.

weight of the rivets and the necessary overlapping of plates, and the labor involved in making holes for the rivets is eliminated. For products in which airtight or liquid-tight seams are required, welding is the superior method of fabrication. In many uses welding is displacing bolting as a means of assembly. Welding is also competing with casting as a fabricating method. Units which ordinarily are cast in one piece can be built up instead by welding plates and other steel shapes together.

Growth in the use of welding is related to the trend of production in industries in which it finds greatest application, as well as to its displacement of other methods of joining metals. The extent of the use of welding in a particular industry is in turn dependent upon the functions which welding techniques perform in that industry. Welding applications can be divided into five main types: Maintenance welding, salvage welding, toolroom welding, construction welding, and production welding. Maintenance welding may be found in any industry in which the repair of metal parts is carried on, and in many localities throughout the country there are independent repair shops specializing in welding repairs. Frequently, when welding is used as a repair process, the welding is done not by welders but by other workers such as machinists or automobile mechanics. In its salvage function, welding is used to reclaim for use in production defective castings and other parts which would otherwise be scrapped. Thus, this application would be found mainly in certain metalworking industries. Welding is used in tool and die shops in the making of jigs and fixtures. The use of welding as a construction tool is limited mainly to pipe-line construction and to structures made at least partly of metal. In production welding the process is simply used as one of the steps in the fabrication of the final product of a manufacturing plant. Of these five functions of welding, production is the most important from the viewpoint of the employment outlook for welders. Maintenance work creates a substantial and relatively stable demand for welding, but the potential expansion of the use of welding is more dependent upon its application in production processes.

Welding employment before the war was distributed among a large number of industries because of the widespread use of welding in maintenance. The greater part of the employment, however, was concentrated in a relatively few industries—automobiles, machinery, miscellaneous iron and steel products, electrical equipment, ships and aircraft—which use welding in production as well as in maintenance and other functions. Data from the Census of Population, presented in table 1, show for March 1940 the distribution of the 121,000 employed male welders, by industry.

Machine welders constitute the larger group of the welders employed in automobile manufacturing, especially in the production departments. Many of the hand welders are employed in the maintenance departments and in the tool shops (making jigs and fixtures). Various automatic resistance-welding machines are used in many phases of the body assembly, as well as in such components as gas tanks and mufflers. Even when arc welding is used it is often done by automatic arc-welding machines, which eliminate the need for skilled hand welders. Hand welding is used in production chiefly on parts difficult to reach.

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TABLE 1.—*Employment of Male Welders and Flame-Cutters, by Industry, March 1940*[1]

Industry	Number employed[2]		Male welders and flame-cutters as per cent of total employment in each industry[3]
	Number	Percent of total	
All industries	121,380	100.0	0.3
Manufacturing industries	89,120	73.4	.8
Blast furnaces, steel works and rolling mills	9,980	8.2	1.8
Miscellaneous iron and steel industries	16,420	13.4	2.4
Miscellaneous machinery	11,100	9.2	2.0
Agricultural machinery and tractors	1,720	1.4	1.9
Electrical machinery and equipment	4,520	3.7	1.2
Miscellaneous nonferrous-metal products	1,280	1.1	1.1
Automobiles and automobile equipment	18,280	15.1	3.2
Aircraft and parts	2,020	1.7	1.9
Ship and boat building and repairing	9,000	7.4	5.9
Railroad and miscellaneous transportation equipment	1,280	1.1	2.8
Furniture and store fixtures	1,720	1.4	.8
Petroleum refining	1,700	1.4	.9
Miscellaneous chemical industries	1,480	1.2	.4
Other manufacturing industries[4]	8,620	7.1	.1
Nonmanufacturing industries	31,220	25.7	.1
Construction	4,560	3.7	.2
Railroads (including repair shops)	5,300	4.4	.5
Gas works and steam plants	1,100	.9	1.3
Crude petroleum and natural gas	1,860	1.5	1.0
Miscellaneous repair services and hand trades	10,180	8.4	6.3
Automobile storage, rental, and repair services	1,620	1.3	.3
Other nonmanufacturing industries[5]	6,600	5.5	(6)
Industry not reported	1,040	.9	.1

[1] Excludes those employed on public emergency work. Data are from the Census of Population: 1940, The Labor Force (Sample Statistics), Occupational Characteristics.

[2] The distribution of welding employment by industry is based on a 5-percent sample of Census returns. The total is therefore slightly different from the total shown in table 2, of 122,688 employed male welders and flame-cutters, which is based on a complete count of Census returns. In addition, there were 2,653 female welders and flame-cutters employed, but no data on their distribution by industry are available.

[3] Total employment in each industry includes proprietors, managers, and officials, as well as wage and salary workers.

[4] Includes all manufacturing industries which employed fewer than 1,000 welders and flame-cutters and manufacturing industries not elsewhere classified.

[5] Includes all nonmanufacturing industries which employed fewer than 1,000 welders and flame-cutters.

[6] Includes less than a tenth of 1 percent.

A common use of welding in machinery production is in fabricating the bases and frames of the machines, where welding often replaces castings. Among the machinery industries, construction machinery makes the greatest use of welding in production. Welding is also an important occupation in the manufacture of blowers and fans, industrial cars and trucks, oil-field machinery, and mining machinery.

Welding is of considerable importance in the manufacture of electrical appliances but most of the welders are resistance machine welders. Hand welding is moderately important in the manufacture of electrical generating and distributing equipment.

The industrial distribution of welding employment is reflected in the geographical location of welders in 1940. It is evident from table 2 that the employment of welders is concentrated in the industrial Middle Western and Middle Atlantic States, with large numbers also employed in California and Texas. Some welders and flame-cutters were reported in every State, however, showing the influence of the demand for welders in maintenance work.

TABLE 2.—*Employment of Male Welders and Flame-Cutters, by Region and State, March 1940* [1]

Region and State	Number employed	Percent of total	Region and State	Number employed	Percent of total
United States	122,688	100.0	South Atlantic—Continued.		
			Virginia	1,955	1.6
New England	6,292	5.1	West Virginia	1,339	1.1
Maine	547	.4	North Carolina	470	.4
New Hampshire	244	.2	South Carolina	459	.4
Vermont	88	.1	Georgia	918	.7
Massachusetts	3,783	3.1	Florida	683	.6
Rhode Island	273	.2			
Connecticut	1,357	1.1	East South Central	4,109	3.3
			Kentucky	1,015	.8
Middle Atlantic	26,095	21.2	Tennessee	1,248	1.0
New York	8,235	6.7	Alabama	1,285	1.0
New Jersey	4,678	3.8	Mississippi	561	.5
Pennsylvania	13,182	10.7			
			West South Central	8,765	7.1
East North Central	47,569	38.8	Arkansas	413	.3
Ohio	12,189	9.9	Louisiana	1,378	1.1
Indiana	5,255	4.3	Oklahoma	1,628	1.3
Illinois	9,344	7.6	Texas	5,346	4.4
Michigan	16,636	13.6			
Wisconsin	4,145	3.4	Mountain	2,282	1.9
			Montana	280	.2
West North Central	8,049	6.6	Idaho	238	.2
Minnesota	1,466	1.2	Wyoming	225	.2
Iowa	1,567	1.3	Colorado	628	.5
Missouri	2,782	2.3	New Mexico	248	.2
North Dakota	105	.1	Arizona	273	.2
South Dakota	125	.1	Utah	317	.3
Nebraska	480	.4	Nevada	73	.1
Kansas	1,524	1.2			
			Pacific	11,062	9.0
South Atlantic	8,465	7.0	Washington	1,567	1.3
Delaware	359	.3	Oregon	676	.6
Maryland	2,140	1.7	California	8,819	7.2
District of Columbia	142	.1			

[1] Census of Population: 1940, Volume III, The Labor Force, Reports by States, Parts 2 to 5. Excludes those employed on public emergency work. These data are based on a complete count of Census returns, and the total is therefore slightly different from the total shown in table 1, of 121,380 male welders and flame-cutters employed (except on public emergency work), which is based on a 5-percent sample of Census returns.

Wartime Employment of Welders

The phenomenal expansion in the use of welding as a production tool, brought about by war production demands, resulted in a tremendous increase in the employment of welders. By the end of 1943, the high point of employment in munitions industries, the estimated number of welders and flame-cutters had risen to a peak of 364,000—about three times the total of 124,700 shown by the 1940 Census. The nature of wartime production requirements accentuated the importance of hand welders in comparison with machine welders. Of the estimated total welders and burners, about 290,000 were hand welders using electric-arc or acetylene-gas equipment. Operators of welding machines (spot, butt, flash, etc.) numbered about 26,000, and burners comprised the remaining 48,000. These wartime totals represent a much greater relative as well as absolute increase over peacetime figures for hand welders and burners as compared to the machine welders. The magnitude of the wartime increase in welding employment has established hand welding as the largest single skilled occupational specialty in the metalworking field.

The urgent wartime demand for welders, coupled with the general shortage of manpower, enabled women to take over a large number of the welding jobs. Women were also relatively better qualified to meet the physical demands of welding work than they were for many other

jobs. In December 1943, it is estimated that women constituted about 15 percent of the total employment of welders and burners. This percentage was undoubtedly increased during 1944. Thus welding represented a major occupational opportunity for women in the war period. The largest numbers of women welders were engaged in hand welding, although the ratio of women to men was greater in resistance-welding jobs.

The remarkable growth of welding employment during the war was attributable primarily to the extensive use of welding in ship construction. Some new applications of welding in other fields and the general high level of production of metal goods also stimulated a demand for welders, but shipbuilding was by far the major cause of the expansion of welding employment. The result was that the high wartime employment of welders was based mainly on two related factors—the large-scale acceptance of welding methods in ship construction, and the importance of the ship-construction program to the United States war effort.

The data presented in table 3 showing the industrial distribution of welding employment in the war period clearly indicate the effect of the shipbuilding demand. An estimated total of 180,000 welders and burners was employed in public and private shipbuilding in December 1943, as compared with 9,000 shown by the Census in 1940—an increase of 1,900 percent. The welders and burners employed in shipbuilding constituted almost half of the total employment of welders and burners, and the increase in shipbuilding accounted for over 70 percent of the total increase.

A sharp gain in employment of welders in the manufacture of aircraft and aircraft engines was also shown. The 16,000 welders shown for the aircraft category do not account for all the welders actually employed in production of aircraft and parts during the war. The industries shown in the table are classified on the basis of their prewar product, so that the production of aircraft in converted plants is covered in other industries. The many welders employed on ordnance production in converted plants are included under several different categories, principally iron and steel, automobiles, and machinery. The welders in new ordnance plants and Government arsenals are covered under the iron and steel group. Plants comprising the prewar automobile industry showed a comparatively small increase in the number of welders employed. This was principally because the production of passenger automobiles, which had required large numbers of welders, was virtually eliminated. The welders in the converted automobile plants were engaged in the production of military tanks and other ordnance items, army trucks, aircraft parts, and aircraft engines.

Developments in recent years have established welding as the principal method of joining, in the construction of steel ships, it having almost completely displaced riveting and other techniques for this purpose. Figures from prewar and wartime surveys of shipbuilding employment show strikingly the growing importance of welders in shipbuilding. In August 1936, 4.3 of the total production and supervisory workers in shipyards were welders, whereas in June 1943 their number had increased to 9.7 percent of the total.[2]

[2] See Employment in the Shipbuilding Industry, 1935–43, in Monthly Labor Review, May 1944.

TABLE 3.—*Employment of Welders and Burners (Flame-Cutters), by Industry, March 1940 and December 1943*

Industry [1]	Number employed			Percent of increase, March 1940 to December 1943
	March 1940 [2]	December 1943 [3]		
		Number	Percent of total	
All industries	124,741	364,000	100.0	192
Manufacturing industries	89,120	331,000	91.0	271
Iron and steel and their products group [4]	26,580	46,000	12.6	73
Electrical machinery group [5]	4,520	12,000	3.3	165
Machinery, except electrical, group [6]	13,080	26,000	7.2	99
Transportation equipment, except automobiles, group	12,300	204,000	56.1	1,558
Aircraft and parts, including aircraft engines	2,020	16,000	4.4	692
Shipbuilding and ship repair, private and public	9,000	180,000	49.5	1,900
Other transportation equipment [6]	1,280	8,000	2.2	525
Automobiles group [7]	18,280	24,000	6.6	31
Other manufacturing industries	14,360	19,000	5.2	32
Nonmanufacturing industries [8]	31,220	33,000	9.0	6

[1] Industries classified by principal 1939 product.
[2] Excludes those employed on public emergency work. Data are from the Census of Population: 1940. The total for all industries is from Volume III, The Labor Force, Part 1: United States Summary. It is based on a complete count of Census returns and includes 2,053 employed female welders and burners (flame-cutters). Data on employment of welders and burners by industry are from The Labor Force (Sample Statistics), Occupational Characteristics, which is based on a 5-percent sample of Census returns and which excludes female welders and burners and 1,040 male welders and burners for whom the employing industry was not reported. Therefore, the number of employed welders and burners shown by industry does not add up to the total of employed welders and burners in all industries.
[3] Estimates prepared in the Occupational Outlook Division of the Bureau of Labor Statistics.
[4] In 1943, includes Government manufacturing arsenals, ordnance production in new plants, and ordnance and other war production in converted plants, as well as production of the 1939 products.
[5] In 1943, includes ordnance and other war production in converted plants, as well as production of machinery.
[6] Includes locomotive and railway-car plants, and for 1943, also includes military tank production in new plants and military tank and other war production in converted plants.
[7] In 1943, includes aircraft engines, aircraft parts, military tanks, and ordnance production in converted plants, as well as production of automotive vehicles.
[8] Includes construction, transportation, service, and other nonmanufacturing industries.

The importance of welding in ship construction varies with the type of ship. A study of the workers in private shipyards in June 1943 [9] revealed that welders were relatively most numerous in yards building tankers; there 15.1 percent of the total employed in production and supervisory jobs were welders. The next highest percentage of welders was found in the building of landing craft, with 12.0 percent, followed by Liberty cargo vessels with 11.3 percent. Welders were least important in repair yards, accounting for only 4.7 percent of the total workers.

Of the total of 180,000 welders and burners employed in shipyards in December 1943, a little over one-fifth were burners. Most of the welders were hand welders, the exception being the operators of automatic arc-welding machines, which have been extensively used in shipbuilding.

Welding has been used for many purposes in aircraft manufacture, mainly in the production of parts and subassemblies rather than in the final assembly of the aircraft. Landing gear, engine mounts, fuel tanks, and bomb bays are examples of aircraft components in which welding is used.

Welding found many uses in ordnance production, especially in tanks, which are now all-welded. Important applications were also

[9] See Employment in the Shipbuilding Industry, 1935–43, in Monthly Labor Review, May 1944.

made in such items as bomb casings, depth charges, and heavy gun mounts, as well as in others too numerous to detail.

The increases in the welding labor force indicated by the threefold increase in employment was achieved through one of the largest training programs ever attempted. An estimated 1,500,000 received some welding training during the war years July 1940–December 1944. A great many of these trainees were actually paid while learning welding in schools maintained in shipyards and factories. The discrepancy between the large number of persons enrolled in welding courses and the estimated peak employment of welders and burners is accounted for mainly by turn-over and the failure of many trainees actually to take or remain at welding jobs.

The greatly expanded use of welding during the war also stimulated the development of new equipment and methods. These developments tended in many cases to reduce the skill required for welding jobs. This reduction was achieved partly through the ability of many producers to break down some of the welding operations under conditions of quantity production.

The great importance to welding employment of such industries as shipbuilding and aircraft has resulted in a considerable shift in the distribution of welding jobs among geographical areas. Largely because of the influence of these war industries, a very large proportion of welder employment during the war was in the coastal States, while in the Middle West welding jobs showed a smaller increase.

Postwar Employment Outlook for Welders

FACTORS AFFECTING THE OUTLOOK

The spectacular increase in the employment of welders during the war and the publicity given to new welding methods and broadened applications in industry have drawn attention to the probable number of postwar welding jobs. Because of the importance of such information in vocational guidance of both returning veterans and high-school students, it is essential to evaluate the principal factors which affect the postwar employment opportunities for welders.

Certain factors stand out as determinants of the number of postwar welding jobs. First is the question of the future changes in the relative use of welding in industry as affected by the continued development of new welding techniques and by increased acceptance and utilization of welding in production. Second, and perhaps more important, is the magnitude of the employment and the direction of the postwar trends in the industries which will probably be the chief users of welding. From the point of view of vocational guidance, a highly significant trend will be the relative use of hand and machine methods of welding, a trend which will be affected by the relative importance of the industries using welding, as well as by advances in technique. Another main factor to be taken into consideration is the effect of improvements in welding methods on the man-hours of employment required to perform a given volume of welding—whether, in other words, they will result in substantial increases in the man-hour productivity of welders.

ADVANCES IN WELDING TECHNIQUES

A full consideration of possible gains in the use of welding would depend upon a complete and objective technical appraisal of welding methods and their points of advantage over other production methods. As indicated previously, welding has many advantages for certain uses and these have contributed to its steady and rapid growth. The influence of the war in hastening the eventual acceptance of welding for many purposes is difficult to measure precisely.

Many of the wartime applications of welding will decline in importance when the output of the products concerned is reduced. However, the manufacturers who gained additional experience in welding, or who installed welding equipment and were convinced of its advantages, will want to carry over welding into their peacetime production where feasible and profitable. The significance of this development cannot be ignored, yet it is easily possible to overstate the importance of many of the new applications that are anticipated for peacetime. In many cases the total volume of employment in the production of the items concerned will never bulk large, because the nature of the product is such that demand is definitely limited. In other instances, the proclaimed new use of welding is of such minute importance in the production process that the resulting new employment of welders can never be very large. A further limitation on the increased use of welding is the extensive use it has already achieved in many industries.

In the production process as now organized, welding can be used only at a certain number of points. Even in those industries in which welding has achieved its greatest use and in which no further large applications are expected, welders will remain only a small proportion of the total labor force, although they may in some cases constitute the largest single occupation. This indicates that even should welding become the principal method of assembly for many additional products, not all nor even a large proportion of the workers will be welders.

RELATIONSHIP OF WELDING TO OTHER INDUSTRIAL PROCESSES

With these limitations in mind, it still appears reasonable that there will be a further expansion in the use of welding in many industries. One of the main areas in which gains are expected by some observers is in competition with castings as components of many types of products. By taking basic metal shapes, such as plates and bars, and welding them together, so-called "weldments" can be fabricated to substitute for castings in many uses. It is not yet possible to generalize regarding the extent and timing of future displacement of castings by weldments. Whether castings or weldments are more efficient in a particular case depends upon such factors as the size and complexity of design of the part and the quantity to be produced. Even if weldments could be established as more efficient, there is considerable inertia to overcome. Many plants have large investments in foundry capacity, and savings from welding would have to be considerable to persuade them to abandon the foundry facilities and install expensive welding equipment. For the most efficient utilization of welding it is usually preferable that the design for the product be made specially for application of welding, and this would have to be

done for countless products in order to achieve widespread displacement of castings. In view of these technical and economic uncertainties, it is most reasonable to assume, in projecting the use of welding, that weldments will be substituted gradually for castings in many fields, but that a substiantial displacement is only a long-run possibility and not at all assured.

Welding will also be in competition with plastics and with the stamping and pressing of sheet metal, but in these instances it is more likely that welding may be affected adversely. Plastics compete with metal products generally, and a large increase in their use could cut into the requirements for welding. The development of methods of stamping larger sections of sheet metal tends to reduce the need for welding in joining smaller units in assembly of many products.

PROSPECTIVE USE OF WELDING IN PARTICULAR INDUSTRIES

An appraisal of the outlook for welding employment is best approached by considering the possibilities in specific industries in which welding is either actually or potentially important. The automobile industry was the largest employer of welders before the war, but employment of them showed much less of an increase during the war than was the case in many other industries, mainly because its normal product was so drastically curtailed. Welding had already achieved a high degree of utilization in automobile production before the war and the possibilities for future expansion are more limited than in other fields where welding was less widely used. The postwar volume of welding employment in this industry will thus be more closely related to its general level of employment. Automobile production is expected to be at high levels for at least several years after the war and may then settle down to a long-run level higher than that immediately prior to the war, if economic conditions are at all favorable. The net result is an indicated moderate increase in welding employment in the automobile industry.

The use of welding varies considerably among the different machinery industries. In many of them there are possibilities for some extension of welding applications. There are definite limits, however, upon the extent of welding in machinery assembly, because of the necessity to provide for moving parts and for ready disassembly of the machine for repairs. One of the main possibilities for increased use of welding lies in the substitution of weldments for castings in such parts as bases, frames, and gears.

There are few industries in the iron and steel group in which a substantial increase in welding can be anticipated. Industries such as fabricated structural steel and boiler shops already make heavy use of welding and will continue to do so. In other industries, however, such as the manufacture of castings, forgings, tin cans, and screw-machine products, the nature of the product precludes significant increases in the utilization of welding.

One of the fields in which welding is likely to have greater use is the manufacture of railroad cars. However, this industry has already been using welding extensively during the war in producing tanks, and any increase over wartime levels in the number of welders employed may be small.

Some opportunities in welding, both for self-employment or as an employee, may arise through the establishment of additional small

welding repair and job shops. The prospects for successful operation of this type of business depend upon such factors as the competition and the potential demand for welding services in the particular community in which the shop is to be located. The proprietor of a small welding shop should possess a combination of all-round welding skill and business ability. There will probably be some continued expansion in this field after the war, but there are limits to the need for such service, and a substantially increased volume of employment cannot be expected.

One of the principal activities which should employ more welders after the war is building construction. Welding is being more extensively used in the erection of metal structures, and the volume of construction after the war is expected to be at very high levels. Much of the construction activity anticipated, however, will be in residential housing, which will probably make but small use of welding.

The industries thus far enumerated are peacetime industries with established civilian markets. The outlook for welding employment in the war industries, which have been important users of welding, is for a considerable decline. A definite drop in the number of welding jobs in aircraft production seems clearly indicated. The steady rise in the importance of welding in aircraft, combined with the fact that many types of planes for civilian use are more suitable for welded fabrication than most of the military planes, indicates that the *percentage* of aircraft workers who will be welders may be even higher after than during the war, but even the most optimistic predictions do not show postwar aircraft employment as more than a small fraction of the wartime peak. The use of welding in the production of tanks and other ordnance will, of course, also be reduced, consistent with the relatively low level of activity in that field after the war.

The industry of crucial importance to postwar welding prospects is shipbuilding, the industry which accounted for almost half of the wartime welder employment. There is definite possibility that the relative importance of welders among shipyard employees may be reduced, because of the elimination of a great deal of the wartime mass production of ships, and because ship repair, which uses fewer welders, will be a larger proportion of shipyard activity. Moreover, total shipbuilding employment will fall far below the wartime level. The possible extent of the decline may be indicated by the fact that the number of wage earners employed in private shipbuilding averaged only 69,200 in 1939 compared with a figure of 1,284,900 in December 1943. No specific forecast of postwar shipbuilding employment has been made in connection with the present study, but to illustrate the effects upon the number of welding jobs of the prospective drop in ship-construction work, the average employment—224,000—in a high prewar year, 1941, may serve as an assumption as to the level of employment that will be reached several years after the war. If shipbuilding employment does stabilize at about that level, it will mean an extremely large reduction in the number of welders required in shipyards—so large that it will dominate the outlook for welders.

GENERAL PROSPECTS FOR WELDING EMPLOYMENT

The net effect of the anticipated decrease in welding employment in shipbuilding, combined with varying trends in other industries, is a

postwar employment estimate for welders amounting to considerably less than the wartime figure. This conclusion is based upon a detailed appraisal of the outlook for welding employment in specific industries, in which the assumptions as to both the use of welding and the postwar level of total employment in each of the industries were relatively favorable. The estimate covered two periods, one immediately following the completion of reconversion and the other relating to an assumed full-employment economy which, it was assumed, would be attained between 5 and 10 years after reconversion. For the immediate postwar period following reconversion, the indicated employment of welders and burners was about 200,000, compared with the wartime peak of 364,000. Even under the assumed full-employment situation, the number of welders and burners would be considerably less than the wartime figure. The principal factor underlying the relatively unfavorable prospects for welding jobs is, as already noted, the drastic reduction in the number of welders in shipbuilding, which more than offsets increases expected in other fields.

EFFECTS OF TECHNOLOGICAL ADVANCES UPON REQUIREMENTS FOR WELDERS

The total demand for welding is indicated by the anticipated use of welding among industries and their volume of employment. Still another factor, however, may influence considerably the actual number of jobs for welders. A great many welding improvements have as their objective the reduction either of the number of welders required for a given volume of welding or the degree of skill required, or both, and it is likely that the degree of future acceptance of welding as a method of fabrication in many industries is related to—perhaps even contingent upon—the cutting of the welder man-hours required in production. Prominent among these innovations are automatic arc- and acetylene-welding machines, which are being applied to an increasing number of production processes. Their main usefulness is in situations involving large quantities. A typical use is the welding of long lengths of steel plate in ship construction. The large mechanical positioners, which revolve the work piece so that all the welding can be done in the easier and faster downhand position, eliminate both some of the welder jobs and a portion of the skill required.

A considerable reduction in man-hour requirements is possible through the use of automatic arc-welding machines and positioners. The experience of one company engaged in constructing welded steel cargo vessels has been that, in certain types of welding, 7 feet of weld can be laid in the time that it takes to weld 1 foot by using manual methods. The use of positioners to place the work for flat horizontal welding has reduced the time required for some welds as much as 50 percent.

POSTWAR SUPPLY OF WELDERS

In order to obtain a balanced judgment as to employment opportunities for welders in general and the prospects for newly trained welders in particular, the indicated postwar reduction in the number of welding jobs must be related to the probable supply of experienced welders. The number of jobs for hand welders will be considerably less than the number at the wartime peak. This might in itself create a presumption of an oversupply of welders. Some of the people who

held welding jobs during the war may not, however, be candidates for postwar welding jobs. This applies to many of the women who entered the occupation, as well as to many men who left their usual occupation to take war work and to those welders who will retire from the occupation because of death, old age, or changing to another occupation.

The possibility of such withdrawals would be a factor tending to reduce the postwar supply. The peak war employment of welders, however, does not measure the total number of people who worked as welders during the war, because it applies only to one period. Many experienced welders who worked at some time during the war were drafted; other turn-over also added to the number who held welding jobs. The estimated total of 1,500,000 persons who received at least a superficial introduction to welding indicates the magnitude of the wartime labor force, although many may not have actually worked at welding for a sufficient period of time to qualify as experienced welders.

The general picture perhaps should be modified to some extent to consider separately the outlook for fully qualified, all-round welders when industries change over from the production-line methods used for large-scale war production to the making of a variety of goods in small quantities. This factor, combined with the limited qualifications of many of the war-period welders who received brief training or who worked at fairly simple repetitive tasks, may imply relatively more favorable prospects for the more highly skilled workers.

Several other factors, however, may limit the need for additions to the skilled welding labor force. Many of the wartime developments resulting in the break-down of welding jobs into less-skilled duties may persist, particularly if a continuation of this trend should be a requirement for expanding the use of welding in some industries. There are also potential pools of skilled labor supply, not previously discussed, which may enter the picture. These consist largely of supervisory workers, many of whom may be forced to accept skilled production jobs if they lose their war jobs and cannot get supervisory jobs in other industries. In shipbuilding alone there were at least 15,000 to 20,000 welding supervisors, including leadmen and foremen, at the war peak, and this source may be drawn upon to fill a large part of the demand for all-round hand welders. These workers are not included in the December 1943 employment estimate of 290,000 hand welders.

EMPLOYMENT OPPORTUNITIES IN WELDING

The balancing of the probable postwar supply of welders against the probable demands of industry leads to the conclusion that the employment opportunities in hand welding for persons without welding experience will be relatively unfavorable for a number of years after the war. This situation also applies to a large proportion of the wartime welders, whose jobs have been highly specialized, and who may find that their welding experience is not readily transferable to many types of peacetime jobs.

Replacement of workers who leave the occupation because of death or retirement probably will not provide a substantial number of job opportunities in welding for many years. Most of the welding labor force is relatively young in contrast to many other occupations having

large proportions of workers in the older age groups in which retirement and death more frequently create job vacancies. Only 16 percent of the employed welders were over 44 years old, at the time of the 1940 Census, compared to over 50 percent in such occupations as carpenters, blacksmiths, and boilermakers.

The nature of the postwar demand for welding employment is likely to result in relatively more favorable opportunities for machine welders than for hand welders. Many of the new welding developments are in the field of resistance-machine welding. In addition, this type of welding is used extensively in the manufacture of many consumer goods—for example, automobiles, refrigerators, electrical appliances—the production of which will be at high levels after the war. During the war the importance of shipbuilding as a source of demand for welding stimulated the employment of arc welders. The prospective greater importance of machine welding among postwar welding jobs is significant from the viewpoint of vocational guidance, because the resistance types of welding do not require preemployment training, a short period of on-the-job training usually being sufficient.

The readjustments related to reconversion from war production will involve considerable shifts in the geographical location of welding employment. The number employed in coastal States, where shipbuilding and aircraft have been important during the war, will be substantially reduced, whereas the Midwest industrial areas should increase their proportion of welding employment, although the actual number of welding jobs in these localities may be no larger than the wartime total.

Training of Welders

Training courses for welding are largely restricted to the teaching of hand-welding methods. Operation of resistance-welding machines is usually learned quickly on the job.

Before the war, the objective of training programs was usually to produce all-round welders, but it was generally considered that the graduates of these welding courses needed a period of work experience before they could actually qualify as such. About 200 hours of welding instruction ordinarily constituted the training programs operated by many industrial companies and served as a standard suggested for trade and vocational schools.

In order to standardize and regulate the scope and quality of training provided for welding, the American Welding Society has sponsored a Code of Minimum Requirements for Instruction of Welding Operators. The first part of this code covers the arc welding of steel $\frac{1}{16}$ to $\frac{3}{4}$ inch thick, and its objective is to provide standards for courses which would produce, not an experienced operator, but one with "enough skill and knowledge so that he will have immediate value to industry as an operator on less-difficult work, and will be able, by gaining experience, to progress rapidly to work of greater difficulty and responsibility." [4]

According to the code, a minimum of 150 hours should be devoted to actual welding, exclusive of time spent in witnessing demonstrations, preparing plates, and testing specimens, and not less than 20 hours to instruction in welding theory.

[4] Published in tentative form in 1942 and as a standard in 1945. The American Welding Society has, in addition, issued a code applicable to instruction for oxyacetylene welding of steel aircraft. Codes are being prepared relating to training for other operations.

Students must pass a specified series of qualification tests (before completing the course), consisting of actual applications of welding, with the requirement that sound welds of various types be produced.

The code also covers the equipment and facilities that should be furnished by the school, in addition to the qualifications and duties of the instructors.

The urgent wartime requirements for a large number of welders to do specialized work resulted in a series of training programs whose scope and length were below the standard of the American Welding Society. These courses have turned out welders able to begin on simple welding jobs, such as tack welding, after 30 hours of instruction, although the training period usually covered about 120 or 130 hours. Between July 1, 1940, and December 31, 1944, approximately 1,500,000 individuals, of whom about 1,100,000 were enrolled in courses sponsored by the U. S. Office of Education, are estimated to have received some instruction in welding, principally in electric-arc welding.

After the war, courses will continue to be given in public and privately operated trade schools. Before taking a course in a private school, the prospective trainee should check on the quality of the instruction offered. Local and State directors of vocational education are good sources of information on this point, and also on the opportunities for instruction in public vocational schools. It should be ascertained whether the school meets the minimum standards provided in the code of the American Welding Society. The local section of the society may be able to provide such information.

In general, welding has not been considered an apprenticeable occupation, although some industrial firms have provided a small number of formal apprenticeships of 3 to 4 years' duration, mainly to train maintenance welders. The Federal Committee on Apprenticeship has viewed welding as a tool of many trades, rather than as a separate trade, and, for that reason, has registered no welding apprenticeship programs.

The skill rating of welders depends to a large extent upon the welding qualification tests they have passed. Qualification procedures have been established by the American Welding Society, the U. S. Bureau of Marine Inspection and Navigation, private insurance companies, and other agencies. In addition, licenses are often required for certain types of construction work in some localities.

The main aptitudes required to be a successful welder are manual dexterity and general dependability. (Physical strength is not so important a factor as in many other types of metal assembly work.) Dependability is essential because it is often difficult to inspect and judge the finished weld and a poor weld, may result in a failure of the complete product at a critical time.

Wages and Working Conditions

WAGES OF WELDERS

The wages of welders are comparable to those of other metal-working occupations requiring equivalent skill and training. A study of straight-time earnings in 18 machinery industries in 1938 and 1939 showed that hand welders averaged 82 cents an hour,

which was lower than the earnings of most of the skilled machine-tool operators but higher than those of semiskilled machine operators.[5] In 1940, hand welders in automobile-manufacturing plants were paid average straight-time wages of $1.03 an hour, which was higher than machine-tool operators' earnings and about the same as the wages of skilled repairmen.[6]

During the war the hourly earnings of welders increased greatly, in accordance with the general advance in wages. As shown in table 4, welders' earnings reached particularly high levels in shipbuilding, a high-wage industry. In the fall of 1942, straight-time hourly earnings of first-class welders in Atlantic coast ship-construction yards averaged $1.52 and those of other classes, $1.17. Hourly earnings in Pacific coast shipyards were somewhat lower, with first-class welders averaging $1.20 and other classes $1.07. On the Atlantic coast, first-class welders were among the highest-paid workers, but on the Pacific coast many occupations earned more than the first-class welders. This geographic difference, which is in contrast to the generally higher wage level of Pacific coast yards, may be explained primarily by the prevalence of incentive-pay systems in Atlantic coast ship-construction yards.

In most of the machinery industries employing substantial numbers of welders, male first-class welders in 1942 earned slightly over $1.00 an hour on the average, ranging from $1.28 in the communication-equipment industry to $0.94 in textile-machinery plants. However, it is important to note that industry averages conceal major variations among plants within each industry.

In the machinery industries, the earnings of first-class welders tended to approximate those of first-class turret-lathe operators and bench assemblers.

TABLE 4.—*Wartime Earnings of First-Class Hand Welders* [1] *in Selected Industries* [2]

Industry, and year of study	Average hourly earnings [3]	Industry, and year of study	Average hourly earnings [3]
Transportation equipment (except automobiles):		Machinery, except electrical (1942):	
Ship construction, private (1942):		Construction machinery	$1.01
Atlantic Coast	$1.52	Oil-field machinery	1.07
Pacific Coast	1.20	Mining machinery and equipment	1.00
Ship repair, private (1943):		Tractors	1.15
Atlantic Coast	1.20	Internal-combustion engines	1.00
Pacific Coast	1.35	Machine tools	1.05
Aircraft engines (1943) [4]	1.30	Machine-tool accessories	1.15
Metal airframes (1943)	[5] 1.25	Miscellaneous metalworking machinery	.97
Electrical machinery:		Textile machinery	.94
Generating, distribution, and industrial apparatus (1942) [6]	1.25	Food-products machinery	.95
Electrical appliances (1942) [6]	1.06	Refrigerating equipment	1.15
Communication equipment (1942)	1.28	Miscellaneous industrial machinery	1.01

[1] Males only, except in ship construction and ship repair, in which earnings of both males and females are included.
[2] Data are from studies by the Bureau's Division of Wage Analysis.
[3] Straight-time earnings of day-shift workers.
[4] Includes converted automotive engine and equipment plants.
[5] Earnings of gas welders only.
[6] Includes plants converted to war production.

[5] See Earnings of Machine-shop Employees, 1936-39, in Monthly Labor Review, November 1940.
[6] See Wage Structure of the Motor-Vehicle Industry, in Monthly Labor Review, February and March 1942.

WORKING CONDITIONS

The working conditions characteristic of the welding occupation result from two groups of factors: those inherent in the use of welding equipment and those associated with the various industrial processes in which welding is employed. In general, the working conditions peculiar to welding compare favorably with many other metalworking operations, but those arising from the industrial environment of welding vary greatly among industries.

Welding is accompanied by moderate physical strain, and, in many of its applications, by a marked degree of monotony. The welder must exert close attention and employ considerable muscular control to guide the arc or flame along the edges of the metal. In common with other metalworkers, he is subject to the noise and dust characteristic of metalworking establishments. Shipyards and construction projects are among the least favorable of welding environments, and machinery and automobile plants the most satisfactory.

The hazards of welding operations, apart from those peculiar to the various industries in which welding is employed, can be almost entirely avoided by the properly equipped and trained worker. The hazards of electric-arc welding include, principally, minor skin burns and "welders' flash" (a temporary eye injury) both of which are caused by exposure of the unprotected skin or the naked eye to the ultraviolet and infrared radiations of the arc; and, infrequently, electric shock, caused either by carelessness or by defective welding equipment. In oxyacetylene welding or cutting, there exists the possibility of explosion or fire, resulting from leaks in oxygen or acetylene lines, or from improper handling. Welding or cutting certain metals by any method may generate harmful fumes or gases, necessitating forced ventilation of the workplace or the wearing of respirators. Other common, but preventable, accident factors include spattering metal or slag, and the danger of fire. Resistance-welding operations are largely free from the hazards characteristic of the hand methods.

The prewar industrial distribution of welding employment shows that welding has been conducted principally in industries with relatively good safety records. The injury frequency and severity rates of the machinery and automobile industries, major peacetime employers of welders, have been markedly below the rates for all manufacturing. Among other important employers of welders, only the fabricated-structural-steel and boiler-shop products industries showed injury-frequency rates well in excess of the average for all manufacturing.

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