UNITED STATES DEPARTMENT OF LABOR
L. B. Schwellenbach, *Secretary*

BUREAU OF LABOR STATISTICS
A. F. Hinrichs, *Acting Commissioner*

Employment Outlook in Foundry Occupations

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UNITED STATES DEPARTMENT OF LABOR,
BUREAU OF LABOR STATISTICS,
Washington, D. C., May 17, 1946.

The SECRETARY OF LABOR:

I have the honor to transmit a report on the employment outlook in foundry occupations. 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. The study was made under the supervision of Richard H. Lewis. Part 1 of this report was prepared by Calman R. Winegarden and Mr. Lewis, with the assistance of Claire L. Labbie. Part 2 was prepared by Mr. Winegarden. Most of the material is reprinted from the Monthly Labor Review, December 1945 and April 1946. The Bureau wishes to acknowledge the cooperation received from officials of trade associations and trade-unions in the foundry industries.

A. F. HINRICHS, *Acting Commissioner.*

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

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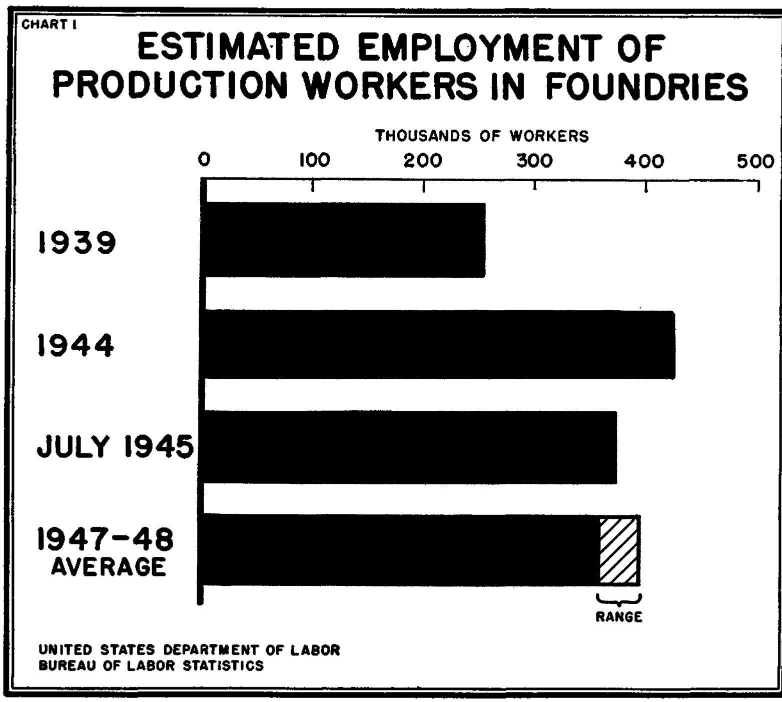
EMPLOYMENT OUTLOOK IN FOUNDRY OCCUPATIONS

Summary

Foundry work will provide relatively good employment opportunities for beginners during the next 2 years. Foundries are likely to need at least as many workers in 1947 and 1948 as they had at the war's end, unlike most other metalworking occupations where jobs will be considerably below the wartime level. Chart 1 shows what has happened to foundry employment recently and what is expected in the near future.



After the next several years, employment in foundries will tend to drop slightly, largely as a result of expected technical advances. Nearly all those who get foundry jobs in the favorable period immediately ahead, however, should be able to hold their jobs.

There are differences in the employment outlook for the various classes of foundries. In 1947–48, employment in gray-iron and malleable-iron foundries will rise much above the wartime peak; in the longer run, it will probably decline somewhat, although remaining higher than prewar. Steel foundry employment in 1947–48 is expected to be a little less than it was at the end of the war, but should hold fairly steady thereafter. The number of jobs in nonferrous foundries during the next few years may be only about half of the wartime total; the outlook thereafter is for moderate growth.

There are also important differences in outlook among the various foundry occupations. Employment opportunities, as well as the work, training, and earnings, in specific kinds of foundry jobs are summarized in the following pages.

MOLDERS

Nature of the work.—Molders prepare the sand molds in which metal is cast. All-round hand molders (journeymen) use mainly hand methods to make widely varying kinds of molds. Less-skilled hand molders specialize on a single kind of mold. Machine molders operate machines which simplify and speed up the making of molds. In addition, there are skilled specialized jobs and supervisory positions in molding departments.

Number employed.—About 75,000 molders were employed in 1944.

Training.—Completion of a 4-year apprenticeship, or the equivalent in experience, is needed to become a journeyman molder, and thus to qualify for all-round hand molding and for the skilled specialized or supervisory jobs. Men with this training are also preferred for many kinds of machine molding. For the less-skilled hand or machine molding jobs, from 2 to 6 months of on-the-job training is usually required.

Outlook.—In general, the employment outlook for molders is favorable. Among the various types of molders, however, prospects are best for journeymen molders, because of their varied skills. During the next few years, more journeymen will be needed than are now available and there will be many openings for apprentices to the trade. Over a longer period, greater use of machine molding and other technical advances will cut down the number of openings for new workers, but those who have established themselves in the occupation should continue to have jobs.

For at least several years, there will be enough jobs for experienced less-skilled hand molders, but few opportunities for beginners are expected. Technical advances will affect this kind of molding more than the other types, and employment of these men gradually may be reduced. However, those who get the equivalent of the journeyman's training through their experience on the job will have very good chances for continued employment.

In 1947 and 1948, not quite as many machine molders will be needed as were employed in this work during the war. Many of these workers have left the occupation for other kinds of jobs, however, and some openings to learn machine molding are expected. Longer-run prospects are for a fairly steady number of jobs for machine molders. If enough journeymen are trained, however, they may replace some of the less-skilled machine operators.

Earnings.—Molders are among the best-paid foundry workers. In January 1945, typical hourly earnings, not including overtime, were between $1.10 and $1.35.

COREMAKERS

Nature of the work.—Coremakers shape the bodies of sand, or "cores," which are placed in molds in order to form any hollow spaces needed in castings. All-round (journeymen) coremakers perform by hand the more intricate and varied types of work, operate certain kinds of coremaking machines with little supervision, or direct a number of less-skilled coremakers. Semiskilled hand coremakers handle the simpler and more repetitive jobs. Coremaking machine operators specialize in running one of several kinds of machines used as substitutes for hand work.

Number employed.—About 30,000 coremakers were employed in 1944.

Training.—Journeymen coremakers must go through an apprenticeship—usually of 4 years—or have equivalent experience. (Molding and coremaking training is often combined in a single molder apprenticeship.) Semiskilled work, hand or machine, requires only brief training—sometimes less than 30 days.

Outlook.—Employment prospects vary among the different grades of skill. There will be a shortage of journeymen coremakers for at least several years, and, as a result, a number of apprenticeships should be available. Following this period, employment opportunities will decline, owing mainly to growing mechanization of coremaking. This should not, however, seriously affect the employment of experienced journeymen, since they will be used, to an increasing extent, in machine operating jobs.

Semiskilled hand coremakers have less favorable prospects. There will probably be enough jobs during the next 2 years or so for experienced workers as well as for a few trainees; but, in the longer run technical advances may eliminate the jobs of some of these persons.

The number of jobs for machine coremakers is expected to remain stable for some time. Opportunities for a small number of beginners are likely in the period immediately ahead. If enough journeymen coremakers become available, they may eventually fill a large number of machine-operating jobs in place of the less-skilled operators.

Earnings.—The pay of coremakers is about the same as that of molders. In January 1945, most coremakers earned between $1.15 and $1.30 an hour, excluding overtime pay.

PATTERNMAKERS

Nature of the work.—Patternmakers are highly skilled craftsmen who construct patterns and core-boxes (forms used to shape molds and cores). They usually specialize in making either wood or metal patterns and core-boxes. Their work is done in specially equipped pattern shops, which often are entirely separate from foundries.

Number employed.—About 14,000 journeymen patternmakers were employed in 1944.

Training.—A 5-year apprenticeship is the main method of qualifying as a journeyman patternmaker. Because of the skill needed, it is very hard to get the necessary training any other way.

Outlook.—There will probably be more jobs for patternmakers in 1947 and 1948 than either during or before the war; but there should also be enough trained men to meet this increased need, because most experienced veterans have returned to the trade. Therefore, the number of openings for newly trained journeymen will be limited mainly to the replacement of patternmakers who die or retire—a total of probably not more than about 2,000 in the next 5 years. However, there should be considerably more apprentice openings than this figure indicates, because many apprentices drop out before completing their training.

After several years of high employment, the number of patternmakers jobs will decline slightly. This will result, however, mainly in reducing opportunities for new workers rather than leading to the unemployment of experienced men. In the longer run, no further increase is foreseen, and employment will remain about the same.

Earnings.—Patternmaking is among the best-paid occupations in manufacturing industries. Straight-time hourly earnings in January 1945 were typically between $1.25 and $1.45 in foundry pattern shops and ranged up to over $2.00 in some independent pattern shops.

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OTHER FOUNDRY OCCUPATIONS

There are many types of foundry work for which apprenticeship is not usually needed but which, taken together, provide a large number of jobs. The more important of these occupations include chippers and grinders, castings inspectors, foundry technicians, sand mixers, and melters.

Chippers and Grinders

A chipper uses pneumatic or hand chipping tools to remove excess metal from castings. A grinder operates an abrasive wheel which smoothes and finishes castings. Chipping and grinding may be separate occupations or may be combined in one job. The work is generally learned in a brief period of on-the-job training. Considerable experience is needed, however, to do some of the more difficult chipping and grinding work.

Employment prospects for the next few years are generally favorable. Although there will be slightly fewer jobs than there were during the war (about 50,000 were employed in 1944), the transfer of experienced chippers and grinders to other kinds of work has reduced the supply, creating openings for many newcomers. Over a longer period, the number of chipping and grinding jobs will decline slightly, but it is not likely that the more efficient of these workers will be unemployed.

Typical earnings of chippers and grinders, as of January 1945, were between $0.90 and $1.10 an hour for straight time.

Castings Inspectors

These workers check finished castings for structural soundness and proper dimensions. The more-skilled inspectors work from blueprints and inspect various types of castings. The less skilled do routine measuring and checking under supervision. A brief period of on-the-job training is needed for the less-skilled work. The more-skilled jobs are usually filled by promoting either inspectors of lower grade or chippers and grinders. A total of about 15,000 inspectors were employed in 1944.

There will probably be a strong demand for skilled inspectors for at least several years. Since relatively few were trained during the war, there should also be opportunities for a limited number of foundry workers to be upgraded to those jobs. On the other hand, there will probably be more persons experienced in the less-skilled type of inspection work than will be needed. However, enough of these workers have shifted to other jobs to create some openings for trainees. The longer-run outlook for both types of inspectors is for a fairly steady level of employment.

In January 1945, the more-skilled inspectors generally earned between $1.05 and $1.20 an hour, excluding overtime. In the lower-skilled grades, earnings were from 5 to 25 cents less per hour.

Foundry Technicians

This is a group of skilled occupations, including such jobs as testing molding and coremaking sands, making chemical analyses of metals, and using X-ray apparatus to examine the internal structure of castings.

The work is learned mainly on the job. However, a high-school education is usually needed and, in some cases, additional technical schooling may be required.

There will be good opportunities for foundry technicians, experienced men as well as some beginners, during the next few years. This is a growing field, because of the long-run trend toward more use of scientific methods in foundries. However, because of the small number of persons employed and the gradual growth expected, only a limited number of openings will occur in any one year.

Sand Mixers

Sand mixers clean, moisten, and mix sand to prepare it for use in molding and coremaking. This may be done either by hand or machine. Only a brief period of on-the-job training is necessary.

In the period immediately ahead, there will probably be somewhat fewer jobs for sand mixers than there were during the war. (In 1944, there were about 10,000 sand-mixing jobs.) However, since many experienced sand mixers have changed over to other occupations, there should be some openings for men to learn the work. Increased use of machine methods in sand mixing will eventually cut down on the number of jobs for hand mixers, but those experienced in using sand-mixing machines should continue to have jobs.

Typical straight-time hourly earnings of sand mixers in January 1945 were between 80 and 90 cents.

Melters

A foundry melter operates or directs the operation of a furnace used to melt metal for castings. Skill depends on the amount of supervision given the melter and the kind of furnace he uses. The simpler melting work is quickly learned on the job. The usual way to get into the more-skilled type of melting is to begin as a furnace helper and work up to the job of melter.

During the next few years there should be some opportunities for beginners to learn skilled melting, since many of those experienced in this work are relatively old and will have to be replaced within the next 5 or 10 years. There will also be a limited number of openings for new men in the simpler melting jobs. The number of jobs for melters should hold fairly steady for some time, although the skill needed will gradually be reduced.

WORKING CONDITIONS IN FOUNDRIES

The working environment varies greatly among individual foundries. In some, the conditions compare favorably with metalworking industries generally. In other foundries, safety and comfort are far below the average for metalworking. The injury rate in foundries tends to be relatively high, but there has been considerable improvement of working conditions in recent years.

The frequency of accidents also varies among the different kinds of foundry work. In general, patternmaking and coremaking are the least hazardous, molding is somewhat more unsafe, and jobs in melting and chipping tend to have among the highest injury rates.

Part 1.—Outlook for Foundry Employment

Foundry Products and Processes

Foundries comprise that branch of metalworking which produces castings, i. e., metal objects shaped by pouring molten metal into molds and allowing the metal to solidify. This constitutes a basic and distinct process among the major metal-shaping methods, which also include machining, forging, stamping, rolling, and drawing.

The casting process is highly versatile: it serves as an economical means of forming a wide range of intricate shapes, possessing considerable strength and rigidity, and varying in size from several ounces to many tons. Castings are therefore very extensively used as components of a great variety of metal products. Although some finished articles are cast, the bulk of castings output flows into the metal-fabricating industries to serve as integral parts of their final products. Among the many applications of casting, these are illustrative: Automotive cylinder blocks, farm-machinery gears, railway-car wheels, locomotive frames, ship propellers, bearings, valve bodies, machine-tool beds, ingot molds, water mains, bathtubs, radiators, washing-machine agitators, and kitchen utensils.

METALS USED IN CASTING

Casting is applicable to a number of basic metals and their alloys, classified into four broad groups—cast iron, steel, malleable iron, and the nonferrous alloys. "Cast iron" is a technical term embracing gray, white, mottled, and chilled iron, among which gray iron is quantitatively the most important. Cast steel includes carbon and alloy steels, further classified according to relative carbon and alloy content. Malleable iron is an originally brittle "white iron" converted by a heat-treating cycle into the malleable product. The nonferrous alloys are subdivided according to their dominant elements—copper, aluminum, magnesium, lead, zinc, tin, and nickel. Aluminum, magnesium, and the principal copper-base alloys, brass and bronze, provide by far the largest tonnage of nonferrous-metal castings. The selection of a particular metal for casting a given object depends upon both the physical properties required in its end use and the relative cost of the various metals.

THE CASTING PROCESS

A brief and general description of sand casting will serve as a starting point for a subsequent analysis of technological trends.

The primary characteristic of casting is the reproduction of the model or "pattern" of a desired object. The pattern forms the mold cavity and thus determines the shape of the casting. It is often made in two or more parts to permit withdrawal from the mold, and must be larger than the intended casting, in order to allow for shrinkage of the metal in solidifying and for removal of metal in machining. Wood patterns are built up by gluing and fastening wood segments shaped by hand tools and mechanical woodworking equipment. Metal patterns are usually cast from an original wood pattern, but may be machined from cold metal stock. Plaster patterns are formed by carving or scraping plaster while soft.

In sand casting, the oldest and most common of the various foundry methods, the first step is the preparation of the molding sand, in order to insure the necessary qualities of cohesion, heat resistance, and porosity in the molds. A binding material is added to the sand, and the sand is mixed by hand or by mulling or mixing machines.

A mold is usually made in two parts, the lower half being known as the "drag" and the upper half as the "cope"; the corresponding sections of the molding box, or "flask," are similarly designated. The drag flask is placed upside down on a flat molding board and the lower section of the pattern is set on this board. The flask is filled with molding sand, and the sand is tightly compacted around the pattern. Following this operation, the drag is rolled over. With the top surface of the drag of the mold as its base, the cope section is prepared in like manner. Passages through which molten metal will be supplied are formed in the cope. The two parts of the mold are then separated and the pattern is withdrawn, leaving a hollow space ("mold cavity") in the sand, conforming to the shape of the pattern. If cavities are required in the casting, they are made by inserting bodies of sand, or "cores," into the mold so that the metal will flow around the cores, forming hollow spaces in the casting. Channels, or "gates," are cut in the sand to permit proper distribution of the molten metal within the mold cavity. The sections are again joined, forming the completed mold.

Molten metal is poured into the feeding passage, or "sprue," of the mold, filling the mold cavity, and the metal is allowed to cool and solidify. After solidification, the mold is broken and the casting extracted, adhering sections of the mold are removed, and the cores are knocked out; this is the "shake-out" operation.

Molten metal for pouring is provided by various types of melting units, such as the cupola, open-hearth, electric, air, crucible, or reverberatory furnaces, each adapted to particular metals and their alloys.

Coremaking, essentially molding in reverse, produces the bodies of sand which form the interior shape of castings. In coremaking, sand is forced into a corebox, which is simply a hollow pattern made of wood or metal, usually in two or more sections. The tightly compacted sand is withdrawn from the corebox, placed on a metal core plate, and transferred to an oven for baking. Complex cores may be made in sections, and assembled by pasting. In some types of molding, the entire mold may consist of a core assembly.

In the cleaning, chipping, and finishing of the castings, metal projections formed in molding are first removed by means of hammers, saws, or shears. Then the rough surfaces of the castings are smoothed by tumbling the castings in a revolving drum or by applying blasts of air mixed with abrasive particles. Any remaining protuberances are removed by chipping with an air-driven chisel, or are burned off by an oxyacetylene flame. Manually or mechanically operated grinding wheels provide the final finishing.

Heat treatment of various types may be applied to the castings, depending upon the type of metal used and the physical properties required. Inspection of the finished castings is the final operation, consisting primarily of checking dimensions and of visual examination for surface imperfections.

TYPES OF FOUNDRIES

The tendency toward specialization of facilities and methods for the casting of one or two particular metals gives rise to several fairly distinct classes of foundries: gray-iron, steel, malleable-iron, aluminum, magnesium, and brass and bronze. The kinds of metals used in a single establishment depend largely on the type of melting equipment and the training and experience of the workers in the plant. However, foundries often operate separate departments in order to cast two or more types of metal; thus, many ferrous foundries have nonferrous departments.

In any consideration of foundries the distinction between "jobbing" and "production" methods of casting is fundamental. In production-type operations, large numbers of castings are made from each design and machine methods are employed to a substantial extent. In jobbing operations, very limited numbers of castings, frequently only one or two, are made from each design, and hand methods predominate. Intermediate between the two is the "semiproduction" type of operations.

Production foundries typically serve mass-production industries which use large quantities of identical castings as components of standardized final products, such as automobiles, plumbing and heating equipment, and household appliances. Jobbing foundries provide castings for incorporation into limited-quantity products, such as machine tools and special-purpose machinery of various types. In practice, the distinction between jobbing and production foundries is partially blurred by the fact that production foundries often do some jobbing work, especially in slack seasons.

Economic Characteristics of Foundry Operations

INDEPENDENT AND "CAPTIVE" FOUNDRIES

Foundry operations may be carried on either as separate enterprises or as part of broader manufacturing processes. The former (independent, or commercial foundries) specialize in casting, selling their output to other plants for incorporation in their products. The latter ("captive," or integrated foundries) are departments or subsidiaries of a parent company to which they transfer their output of castings for final assembly. The employment in a captive foundry is customarily included in the employment statistics of the industry in which the parent company is classified, rather than in one of the foundry industries. This makes it impossible to determine precisely the total number of workers employed in foundry operations.

In considering the employment opportunities for foundry occupations, captive as well as independent foundries must be included, because, being a significant source of foundry jobs, they affect the total opportunities and in many communities provide the only employment for foundry workers.

RELATIVE IMPORTANCE OF VARIOUS TYPES OF CASTINGS

As indicated in table 1, the production of gray-iron castings is greater than the combined total of all other types. Next in order, in total weight of castings produced, are steel, malleable-iron, and nonferrous-metal castings. Gray-iron foundries also have the largest employment, with an estimated 150,000 production workers in 1939,[1] including employment in captive foundries and in cast-iron pipe foundries. Steel foundries are estimated to have employed 40,000 production workers in 1939, nonferrous-metal foundries 35,000, and malleable-iron foundries 30,000 workers.

SIZE CHARACTERISTICS OF FOUNDRIES

Size of foundry is significant because it influences the organization of the production process, including the relative numbers employed in particular occupations, the types of equipment used, and the degree of mechanization.

Among the ferrous-metal foundries, gray-iron foundries are typically small production units. In 1939, of 1,161 independent gray-iron foundries reporting to the Census of Manufactures, only 4 had more than 500 wage earners (production workers). On the other hand, 818 foundries, or about 70 percent of the total number, had fewer than 51 wage earners. About 46,000 wage earners, 79 percent of the industry total, were in foundries which employed fewer than 250 wage earners each.

TABLE 1.—*Production of Castings, by Selected Types, 1929–39* [1]

Type of casting	Production (in net tons of 2,000 pounds) in—					
	1939	1937	1935	1933	1931	1929
Gray iron (except cast-iron pipe and fittings)	5,847,905	6,652,257	(2)	(2)	(2)	(2)
For sale and interplant transfer	3,999,783	4,776,389	2,901,537	1,992,570	2,456,957	5,205,920
Produced and consumed in same works	1,848,122	1,875,868	(2)	(2)	(2)	(2)
Cast-iron pipe and fittings [3]	1,264,329	1,098,413	742,929	519,616	1,191,082	1,736,207
Steel	821,720	1,399,064	575,398	312,225	514,417	1,532,040
Malleable iron	508,040	660,079	433,993	263,463	299,206	735,225
Brass and bronze [4]	93,371	126,281	51,598	36,543	104,633	206,756
Aluminum [4]	32,711	23,315	(2)	(2)	(2)	(2)

[1] Data are from the biennial Census of Manufactures.
[2] No comparable data are available for these years.
[3] These are gray-iron products, but have been given as a separate classification in the Census of Manufactures, from which the data were taken.
[4] Includes only rough castings produced for sale and interplant transfer; excludes die-castings.

Both steel foundries and malleable-iron foundries are generally somewhat larger than the typical gray-iron foundry. Of 164 steel foundries reporting in 1939, 2 had more than 1,000 wage earners and 11 between 500 and 1,000; 17,200 wage earners, or more than half of the total (excluding captive foundries), were employed in plants with more than 250 wage earners. In the malleable-castings industry in 1939, the 23 foundries with 250 or more wage earners employed 10,256 of the 18,041 wage earners. Only 8 independent malleable-iron foundries had fewer than 50 wage earners.

No data are available for aluminum foundries in 1939, but they are known to range widely in size. Independent foundries producing other nonferrous-metal castings are usually quite small; of 600

[1] The term "production worker" is equivalent to the term "wage earner" previously used by the Bureau of Labor Statistics. Workers in maintenance, shipping, and similar departments are included in the definition as well as those engaged in fabrication and processing.

foundries in 1939, only 2 had more than 250 wage earners, while almost 500 foundries had fewer than 21 wage earners.

GEOGRAPHICAL DISTRIBUTION OF FOUNDRY EMPLOYMENT

Because foundries produce parts for other metalworking industries, they are located in every section of the country where metalworking activity is significant. In 1939, there was at least one independent foundry in every State except Wyoming. In spite of this wide dispersion of foundries, foundry employment is concentrated in the principal industrial areas of the country. Over 75 percent of the wage-earner employment in independent ferrous-metal foundries in 1939 was in the 9 States which had more than 5,000 wage earners each (table 2).

TABLE 2.—*Number of Wage Earners Employed in Independent Ferrous-Metal Foundries by State and Industry, 1939* [1]

State	Total wage earners, ferrous-metal foundries	Number of wage earners employed in foundries producing—			
		Gray-iron castings, except cast-iron pipe	Cast-iron pipe	Malleable-iron castings	Steel castings
United States	123,045	58,428	16,488	18,041	30,088
Ohio	18,441	10,697	652	2,566	4,526
Pennsylvania	15,142	4,837	1,334	1,659	7,312
Illinois	13,754	5,128	----	3,225	5,401
Michigan	11,971	7,555	(2)	2,958	(2)
Indiana	8,909	4,916	----	1,976	2,017
Alabama	8,417	(2)	7,847	----	(2)
New York	6,672	3,581	341	1,399	1,351
New Jersey	6,094	2,807	2,247	730	310
Wisconsin	5,765	1,941	----	1,308	2,516
California	4,342	2,410	(2)	(2)	1,193
Massachusetts	3,008	2,384	(2)	(2)	266
Missouri	2,889	1,522	(2)	(2)	984
Connecticut	2,327	1,609	----	(2)	(2)
Tennessee	2,216	(2)	1,180	----	(2)
Virginia	1,373	(2)	(2)	----	----
Texas	1,312	746	(2)	(2)	(2)
Iowa	980	711	----	(2)	(2)
Minnesota	980	669	(2)	(2)	(2)
Maryland	710	(2)	(2)	----	----
Georgia	709	582	(2)	----	(2)
All other States	7,034	4,071	665	661	1,637

[1] Census of Manufactures, 1939. Average employment for year. These data cover only establishments classified in the ferrous-metal castings industries on the basis of their major product, and do not therefore include employment in captive foundries.
[2] Included in total, but withheld to avoid disclosure of operations of individual establishments.

Trends in Foundry Production and Employment

The rate of foundry operations has long fluctuated with general economic conditions, being particularly affected by the extreme variation in durable-goods production. In spite of these variations, foundry production over a period of many years has reflected the long-run expansion of durable-goods manufacture (automobiles, machinery, building supplies, railroad equipment, and household appliances) which provides the principal market for castings.

Prewar trends, 1929–39.—As indicated in table 1, the annual output of castings fell precipitously from the 1929 peak through the years of depression, the most severe relative decline occurring in the production of those types of castings (steel, and brass and bronze) most dependent on activity in the producer durable-goods industries. The high degree of economic recovery in 1937 resulted in major increases in foundry production, although castings output remained well below 1929 levels. Among the cast metals, steel most nearly approached its former peak, owing in large part to the strong demand for railway specialties. Following 1937, the sharply reduced volume of business activity led to a new decline in total castings output. However, the production of cast-iron pipe and fittings moved counter to the general downward tendency, because of the requirements of expanding public construction, and the output of aluminum castings rose in accordance with the trend toward wider industrial applications of aluminum. Thus, in 1939, the last year unaffected by large-scale military demands, the foundry industry as a whole was characterized by low levels of production and employment.

Defense period, 1940 and 1941.—The economic effects of the outbreak of the war in Europe and the subsequent inception of the domestic defense program greatly stimulated the metalworking industries, creating a comparable expansion in the demand for castings. The production of commercial steel castings in 1940 exceeded that of the preceding year by 34 percent, and malleable-iron output rose 18 percent.

In 1941, growing military requirements and high activity in the durable-goods industries exerted a dramatic effect on foundry production. As indicated in table 3, production of commercial steel castings exceeded 1,300,000 tons, representing operations at over 93 percent of rated capacity; the rapidly expanding requirements of the naval and cargo vessel programs and the heavy equipment orders of the railroads accounted for much of the increase. Malleable-iron foundries benefited particularly from the high rates of automotive, railroad-equipment, and agricultural-implement production, which normally provide their principal markets. The extraordinary activity of the machine-tool industry, a significant aspect of the entire period, contributed largely to a marked upswing in gray-iron foundry employment.

TABLE 3.—*Trends in Production of Castings, by Selected Types, 1939–44* [1]

Type of casting	Production (in net tons of 2,000 pounds) in—					
	1944	1943	1942	1941	1940	1939
Gray-iron (including cast-iron pipe and fittings)	[2] 9,794,541	(3)	(3)	(3)	(3)	7,112,234
Steel [4]	1,843,386	1,928,645	1,679,178	1,316,027	797,947	594,147
Miscellaneous castings	1,505,379	1,679,981	1,369,826	844,217	507,692	400,465
Railway specialties	338,007	248,664	309,352	471,810	290,255	193,682
Malleable iron	889,820	849,764	768,496	843,038	565,923	480,578
Aluminum [5]	[2] 213,700	[2] 196,897	[2] 134,066	(3)	(3)	(3)
Magnesium [6]	[2] 99,564	[2] 70,231	[2] 21,622	(3)	(3)	(3)

[1] Data are from the U. S. Bureau of the Census and the War Production Board. Except for gray-iron castings production in 1939, these data are not comparable with those shown in table 1, having been collected on a different basis.
[2] Shipments.
[3] No comparable data are available for these years.
[4] Castings produced for sale only. Data represent slightly less than 100 percent of total tonnage sold.
[5] Excludes die castings.
[6] Excludes die castings. Includes the following quantities of magnesium incendiary-bomb body castings (in net tons): 1942, 4,794; 1943, 38,680; 1944, 58,755.

Conversion period, 1942.—In response to the unprecedented requirements for steel castings in shipbuilding and ordnance production, after the American entry into the war, employment and output in steel foundries climbed throughout 1942 to record levels. However, the curtailment of automobile and agricultural-equipment manufacture during conversion to war production resulted in reduced employment in the making of malleable-iron castings. Gray iron was similarly affected in spite of the continued expansion of the machine-tool industry. The output of cast-iron pipe fell markedly, because of restrictions on nonessential construction.

Large-scale production of aluminum and magnesium castings appeared for the first time, primarily in response to the needs of the mushrooming aircraft program. Extensive construction of new facilities, additions to existing capacity, and numerous conversions of malleable-iron and gray-iron foundries to the production of aluminum and magnesium castings provided this newly required output.

War production, 1943–45.—After the metalworking industries had completed their conversion to war production, the demand for castings rapidly outpaced the available supply. Steel-castings capacity was greatly augmented in 1943 and 1944, particularly in connection with requirements for tank armor and marine castings. The growth of aluminum- and magnesium-casting capacity continued, and production in 1944 reached twice that in 1942. Employment in the casting of brass and bronze was expanded to more than three times the prewar level. The requirements of the military truck program made heavy demands on malleable-iron foundries, compensating for the loss of the peacetime automotive market. Gray-iron employment, although below that of 1941, remained above the 1939 level, owing to such factors as the increased needs of the steel industry and the military truck program.

A shortage of foundry labor developed as a result of this expansion and was intensified by heavy selective service withdrawals, the inducements of higher-paying war industries, and the relatively unfavorable working conditions in many foundries. Special measures for recruiting workers, lengthening of working hours, and various wage adjustments provided some relief, but a deficiency in manpower continued throughout the war.

In 1944, cut-backs in the production of ordnance led to a reduction in steel-castings output, and the falling off of machine-tool manufacture resulted in a small decline in the volume of gray-iron shipments. Nevertheless, the employment of production workers in all foundries had reached an estimated total of 425,000, compared to the 255,000 estimated for 1939, and there was a proportionately larger increase in man-hours, as a result of the lengthening of the workweek. Employment in nonferrous-metal casting showed the greatest relative advance, rising from approximately 35,000 in 1939 to 125,000 in 1944. Steel foundries expanded their employment from about 40,000 to 100,000 over the same period. The number of production workers in the other foundry divisions grew only moderately, from 30,000 to 40,000 in malleable iron, and from 150,000 to 160,000 in gray iron. These variations among the types of cast metals reflects both the special nature of military demands and the curtailment of civilian needs. In the first half of 1945, reduced military requirements led to a slight decline in foundry employment.

Outlook for Production of Castings

FACTORS AFFECTING DEMAND FOR CASTINGS

Demand for castings and the resultant volume of production that can be anticipated are determined primarily by two factors—the level of activity in the principal industries which consume castings and their relative use of castings as compared to parts made by other processes.

Few castings are sold directly to consumers as cast. Almost all are incorporated in producer durable goods, principally machinery and other equipment, and consumer durable goods such as automobiles and washing machines. The industries manufacturing these products are susceptible to sharp fluctuations in demand and consequently in their volume of production. Since foundry activity is so closely related to the requirements of these industries, it is greatly affected by the variations in their production.

Appraisal, therefore, of future castings production must necessarily be based largely upon an assumption as to the level of activity in the durable-goods field. It has here been assumed that a high level of activity—at least equal to the best prewar years—will be maintained. The indicated outlook for employment would require modification should this assumption not prove true. The demand for castings is considered as covering all foundry production, both in independent and in "captive" plants.

The continued development of alternative methods of fabricating parts may also affect the volume of future requirements for castings. Fairly stable relationships have been maintained between the use of castings and such long-established processes as machining, forging, and rolling. Recently, however, other techniques, principally welding, stamping, and die casting, have made significant gains. The extent to which parts made by these methods are substituted for castings is dependent upon engineering and cost-accounting considerations applicable in specific cases. For this reason, the precise effect on the volume of castings production of increases in the use of these competing methods cannot be forecast. What can be done is to indicate the areas of competition and to suggest possible trends.

In die casting, a machine is used which forces molten metal into a metal mold, quickly forming a cast shape. Its advantages include a high rate of production, close tolerances, and good finish on the parts produced. This process has been confined to the nonferrous-metal alloys, principally those with bases of zinc, aluminum, or magnesium. The higher melting temperature of the ferrous metals has prevented their use in die casting. Size and design are also major limiting factors; complex shapes, large sizes, thick sections, and objects with hollow areas are often not well suited to this method. In addition, the high original cost of the die, or mold, limits its use to parts produced in large volume.

As a result, die casting will compete with foundry operations only in the quantity production of small nonferrous-metal castings. The substantial expansion of die casting in connection with wartime demands for aircraft components may provide the basis for more intense rivalry in peacetime, but will affect only a small segment of the entire foundry industry. Die casting will also compete mainly with already mechanized methods, such as machine molding and the permanent-mold process. For these reasons, foundry employment as a whole is not likely to be materially affected.

Welding competes with casting in certain products through the use of weldments. These are metal shapes formed by welding together sections of rolled, machined, or cast metals. Welding made marked progress as a wartime substitute for casting in such applications as the manufacture of agricultural implements. Weldments have been employed in place of castings for machine-tool beds, although this use is still in the developmental stage. In some cases, welding may complement casting, in that the weldment is often built up from a number of individual steel castings. Experiments have indicated that welding provides greater economy in small-quantity fabrication, whereas casting results in lower costs in the longer production runs. In general, no major changes in the relative position of the two methods may be anticipated in the short-run period.

Parts stamped from sheet metal have displaced castings in some uses, particularly when the castings are of thin sections. In general, the method is confined to large-quantity operations, owing to the expense of setting up the necessary equipment, including dies. During the war, stamping made substantial gains in aircraft manufacture, partly as a result of the short supply of castings. In peacetime, further extension of stamping is indicated.

In projecting the production of castings it has been assumed that the demand for castings in the short-run period will not be significantly reduced by introduction of these competitive techniques into manufacture of parts now usually cast. Over the longer-run period there is likely to be a trend, in some uses, toward displacement of castings, but the net effect upon the production of castings may not be great, assuming continued technical progress in casting methods and metallurgy.

PROSPECTIVE PRODUCTION TRENDS

Gray-Iron Castings

The outlook for production of gray-iron castings in 1947 and 1948 is for the attainment of annual production totals somewhat higher than the peak wartime level. This would place the average yearly output at about 10,500,000 tons, or possibly somewhat higher if business conditions are especially favorable. The longer-run outlook is more uncertain. Present indications are that, after a number of years at this high rate of production, the trend of output will decline to some extent but remain considerably above the low level of 1939.

The above expectation rests largely upon the relatively favorable prospects of a number of the more important industrial users of gray-iron castings. The demand for gray iron is less concentrated than for other types of castings, being distributed among a wide range of industries. Several industries stand out as consumers of gray-iron castings. The automobile industry was the largest peacetime user, its 1939 consumption of about 1,200,000 tons representing 20 percent of the total (excluding cast-iron pipe and fittings). Most of this tonnage was produced in highly mechanized foundries operated by automobile companies. Gray-iron castings are used primarily in the engines and chassis of automobiles and trucks, rather than in the bodies. Cylinder blocks and heads, crankshafts, and brake drums are illustrative. A substantial portion of gray-iron output goes to the railway industry and railway-equipment manufacturers; the production of chilled-iron railway wheels alone exceeded 500,000 tons in 1939.

In the machinery field, the machine-tool industry is the most important consumer of gray-iron castings, using them most frequently as bases and beds for the machines—parts large in area and usually of great weight. Machine-tool manufacturers purchase most of these castings from independent foundries instead of operating their own foundries. During 1941, when the machine-tool industry was approaching its wartime peak—a level far beyond peacetime totals—over 30 percent of the gray-iron castings produced by independent foundries was going into machine tools.

The basic steel industry is also one of the largest consumers of gray-iron castings, using them principally for ingot molds and rolling-mill rolls. The ingot molds are very large—usually weighing about 4 or 5 tons—and their useful life is relatively short. As a result, when steel operations are at a high level more tons of ingot molds are produced than of any other single gray-iron product except cast-iron pipe.

Other large consumers are the stove, plumbing and heating equipment, tractor, and agricultural-machinery industries, and producers of many types of industrial machinery. During the war substantial tonnages of gray iron were consumed by the ordnance and shipbuilding industries.

Shipments of cast-iron pipe and fittings—a specialized gray-iron product—go principally to construction, including local water and utility systems. Many other types of gray-iron castings are also used in construction.

The industries consuming gray-iron castings face varying prospects in the postwar period. Many of the more important products using these castings have been curtailed during the war and have accumulated backlogs of demand. In other industries, the outlook is more doubtful, the general volume of sales of producers' machinery and equipment being the uncertain factor. The automobile industry, stimulated by pent-up demand, is expected to operate at unprecedented levels and its consumption of gray-iron castings should be correspondingly high. The amount of castings going into railroad equipment should be substantially higher than before the war. Steel operations will probably be at high rates, although not up to the wartime peak unless industrial production is at very high levels. Other important industries whose consumption is likely to increase are the agricultural-implement, tractor, stove, and household-appliance industries, all of which have favorable postwar prospects.

The anticipated great expansion in construction activity should also contribute heavily to the demand for gray iron, especially cast-iron pipe and fittings.

In contrast are some of the war-expanded industries whose consumption will probably show sharp decreases—ordnance, shipbuilding, aircraft. In the machinery field, the production of machine tools will undoubtedly be below the wartime record, although considerably above the depressed period of 1938 and 1939. In other types of industrial machinery, varying conditions will prevail, some of the industries having been greatly expanded during the war and others having a large proportion of their normal output curtailed. An active demand for gray iron should result from the restoration of full production in some of these latter industries—textile machinery and printing-press machinery, for example.

Malleable-Iron Castings

Production of malleable-iron castings should increase significantly—to as much as 25 to 30 percent—above the 1944 total of 890,000 tons during 1947 and 1948 and remain at this level for several years thereafter. Later, after some of the accumulated demand has been filled, malleable-iron production may taper off somewhat but is not likely to decline much below the peak wartime levels if conditions in the industries which consume the bulk of malleable-iron castings are at all favorable. Wartime production represents a considerable increase over 1939, a depressed year, but output in 1941, a year in which almost all of malleable production was going to civilian products, was but slightly below that of 1943, 1944, and 1945. Production in 1929 also approached the wartime peak.

Most of malleable-iron castings go, in peacetime, to industries that have favorable postwar prospects. In 1940, according to estimates of the Malleable Founders Society, over half of these castings were consumed by the automotive industry, distributed fairly evenly between passenger cars and motor trucks and buses. The high levels of automotive production expected will have a stimulating effect upon the total demand for malleable castings. Another large segment of malleable production goes into the construction field, principally in the form of pipe fittings and equipment for electrical utility installations, such as pole-line hardware. Construction activity also is likely to be at extremely high levels.

Almost 10 percent of the 1940 production was used in railroad equipment, and purchases by railroads are expected to be substantial for a number of years, especially since they have improved their financial position so considerably.

Agricultural machinery and tractor manufacturers comprise another substantial portion of the market for malleable iron, consuming over 5 percent of the output in 1940. The high rate of production anticipated for these industries should result in a strong demand for parts, including malleable-iron castings.

Among the less-important users, such as the manufacturers of industrial machinery, hardware, furniture, and stoves, at least a moderately active demand may be expected from most; and there are no marked instances of particularly unfavorable trends.

Steel Castings

During 1947 and 1948, and also over a longer period, production of steel castings will be at levels considerably below the high wartime totals. A substantial decline in output has already occurred since the 1944 output of 2,445,000 tons of steel castings for sale and for own use. Annual production will probably range between 1,400,000 and 1,600,000 tons for a number of years, although the total might go somewhat higher if business conditions are especially favorable. Although this level is far below that of 1944, it is considerably above the 1939 output of 822,000 tons shown in table 1. Production in 1937—a good production year—amounted to 1,399,000 tons.

The greater part of the record volume of steel castings produced during the war was allocated to the manufacture of military tanks, other ordnance, and ships. Production began to decline in 1944, when heavy cut-backs were made in the tank program.

To offset the loss of demand from war products are the expected heavy requirements of steel castings for many peacetime products. Normally, almost a third of steel-castings output is used in railroad equipment, but during the war this tonnage fell off considerably. Steel-castings producers may be expected to share in a probable increase in equipment expenditures by many railroads. A large proportion of steel-castings output is used in industrial machinery, for many types of which there is likely to be a strong demand. High rates of construction activity should also have a stimulating effect upon steel-castings production, since these castings are used in many types of construction, as well as in construction and road-building equipment.

Aluminum and Magnesium Castings

Production of aluminum and magnesium castings in 1947 and 1948 will probably be only a small proportion of peak wartime output (213,700 and 99,564 tons, respectively), but will continue to be far above prewar levels. Output of both these types of castings showed a tremendous expansion during the war, with many millions of dollars of new facilities added. Aircraft engines, whose peacetime production is likely to be but a fraction of the wartime requirements, consumed the great bulk of aluminum castings and, next to the production of incendiary-bomb castings, were the most important factor in the demand for magnesium castings.

Some aluminum castings have been used in automobile engines and this consumption may increase in importance, but it is improbable that any demand for this source can, in the next several years, offset the decrease in production for aircraft engines. Some aluminum household utensils are cast, but their production is relatively insignificant compared to the wartime totals. After the immediate decline from the war-expanded production totals, the output of aluminum castings should resume its gradual growth, with aluminum castings being specified in many fields where use of light metals is desirable.

Brass and Bronze Castings

Production of brass and bronze castings will be at levels considerably below the wartime volume during 1947 and 1948. The trend of output will, however, remain much higher than in 1939. The volume of nonferrous-metal castings was expanded during the war to many times the prewar level. Among the principal wartime uses have been parts for ships, including propellers and valves; bearings and bushings of many kinds; industrial valves and fittings; and ordnance. The consumption in shipbuilding should decline sharply. Valves and fittings, bearings and bushings, and castings for railroad equipment are important in peacetime, and consumption should be substantial under favorable business conditions. In addition, the postwar volume of shipbuilding is likely to be above the activity in the 1930's.

Technological Trends Affecting Employment

In order to translate the anticipated volume of castings production into an estimate of future requirements for foundry workers, it is necessary to evaluate the effects of prospective changes in man-hour output. Although the output of castings per man-hour is influenced by a number of factors—including the rate of foundry operations, the type and size of castings produced, and the quality of the labor force—in the long run, technological developments constitute the most important element in determining the relationship between employment and production.

NATURE AND SIGNIFICANCE OF TECHNOLOGICAL DEVELOPMENTS

In common with other industrial processes, casting is subject to continuous technological change, embracing wider utilization of previously developed equipment and methods which increase productivity, the improvement and refinement of existing techniques and apparatus, and the introduction of new types of machines and processes. In the following discussion of these trends, some of the principal effects of each process are indicated and prospects for greater application are explored. Particular attention is given to developments in molding, in which technical progress has been especially significant.

Patterns

Substantial increases in molding speed have resulted from the development and extensive use of improved pattern equipment, substituting for the single loose patterns which constitute the basic type. Greater rapidity in molding is provided by patterns mounted on plates which fit over the molding flasks. Both parts of the mounted pattern may be affixed to one metal plate, forming a "match plate," or may be in two sections, either wood or metal, one for each half of the mold. Mounted patterns dispense with the need for hand-cutting gates (channels in the sand), eliminate the time and skill required to determine the proper position of the pattern in the molding flask, and simplify the alignment of cope and drag sections. Many small patterns often are mounted on a single plate, thus multiplying molding output. Mounted patterns, because they are relatively expensive, are more suited to quantity production than to jobbing. Their use is also limited mainly to molds of small or medium size and of relatively simple shape.

Prospects are for increased use of mounted patterns, although they already are widely employed. In part, this will result from recent developments tending to lower the cost of producing match plates.

Molding Machines

Mechanical aids to molding encompass a variety of devices which decrease both labor-time input and skill requirements. One of the most common machines is the squeezer, which compacts the sand in the flask by direct pressure. The squeezer machine, suited mainly to flasks up to the 18 x 20-inch size, saves the considerable effort and moderate skill required in hand-ramming. Similar devices are the machines which jolt or jar the sand-filled flask, serving to pack the sand around the pattern. A roll-over apparatus simply substitutes mechanical power for manual effort in the operations of turning over cope and drag sections. These machines can handle molds weighing up to 10,000 pounds.

Among the devices used to facilitate the withdrawal of the pattern from the mold are the stripping plate, which is essentially a mechanical arrangement for raising and lowering the pattern through an opening in a plate which constitutes the bottom of the flask, and vibration attachments which loosen the pattern from the tightly compacted sand mold.

The sandslinger often provides a rapid and efficient substitute for the hand-ramming of very large molds. This machine shoots wads of sand into the flask with great force, tightly packing the sand around the pattern.

Combinations of these mechanical features are quite common, particularly in highly organized production foundries. A single squeeze-and-jolt machine, with vibration or stripping-plate features, is frequently employed in light production work, and a roll-over and jarring apparatus is used in the making of heavier molds.

In general, molding machines find their most widespread use in the quantity production of light- and medium-weight castings of relatively simple shape. Except for the elementary devices, such as the squeeze and roll-over features, machine molding is often not adapted to intricate molds, and the original cost of the machines tends to restrict their use in jobbing.

Trends in the design of molding machines are toward the development of higher operating speeds, adaptability to larger and more intricate molds, and combination of a variety of mechanical aids in a single apparatus. These improvements will accelerate a long-run tendency toward wider employment of machine methods of molding. In the making of very large molds, hitherto requiring mainly hand operations, the sandslinger and other molding machines will be more extensively used.

Permanent Molds

The permanent-mold process serves primarily in the quantity production of identical castings. In this method, a metal mold, suited to repeated pourings of molten metal, substitutes for the conventional sand mold, ordinarily usable for a single pouring. Too expensive for small-scale production, the permanent-mold process often achieves a substantial saving in long production runs, not only dispensing with the complicated process of preparing a sand mold for each casting, but also greatly reducing skill requirements. Other advantages include finer dimensional tolerances and smoother finish of the cast object. However, it may be applied only to the less-intricate shapes, and permits use only of those casting metals having a lower melting point than the permanent mold itself. Thus, the nonferrous-metal alloys as a group are best adapted to the process; among the ferrous metals, only in the case of gray iron has permanent-mold casting been carried beyond the experimental stage. The use of permanent molds, greatly expanded in connection with wartime production of aluminum and magnesium castings, may be expected to show further increase, particularly when the development of metal molds with higher heat-resistant qualities is completed.

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Centrifugal Casting

Centrifugal casting is another of the quantity-production techniques. In this process, molten metal is poured into a sand, carbon, or metal mold which is rapidly spun about either a horizontal or a vertical axis. This process provides a high rate of production, and superior strength and exterior finish in some types of castings. It has been applied to both ferrous and nonferrous metals; cast-iron pipe constitutes the most common use. However, employment of the centrifugal process has been increasing, within certain limitations regarding size and shape, in the casting of the heavy metals. Centrifuging, a closely related casting method, widens the range of application of the centrifugal principle.

Investment Casting

Investment, or "precision," casting represents a relatively new application of the old "lost wax" principle. In this process, the pattern is made of wax or plastic material and the pattern is surrounded by plaster or other refractory material, which forms the mold. The mold is baked in an oven until the wax or plastic pattern is dissipated, leaving a hollow mold cavity, into which metal is introduced by gravity, direct pressure, or centrifugal force. The investment process has been used particularly in the casting of small objects; its extension to larger sizes is still in the developmental stage. Its major advantages over other casting methods lie in the very close tolerances and fine exterior finish of the castings produced. Although investment casting opens a new field for casting in its application to shapes hitherto machined or forged, it also reduces time and skill requirements in relation to sand casting.

Coremaking Machines

Machine coremaking, like machine molding, is suited mainly to quantity operations and possesses the same primary economies of rapid production and minimum skill requirements. Cores may be machine-made by means of a core turn-over-draw apparatus, essentially a modification of the jolt and roll-over molding machine, in which the core box substitutes for the molding flask. Simple cores may be quickly produced by the die-type coremaking machine: sand is fed into a hopper, impelled by a conveyor screw, and extruded through a detachable tube, the interior shape of the tube forming the exterior shape of the core. Still another device, the coreblower, pneumatically forces sand into the hollow form which shapes the core. The use of coremaking machines is generally confined to the smaller and simpler structures; the limitations are roughly comparable to those of machine molding. Improvements in coremaking machines, increasing their versatility, speed, and automaticity, will result in continued expansion in their use. Apart from the mechanization of coremaking, core-room operations will be affected by a trend in the design of castings toward elimination of complex interior shapes wherever possible, thus reducing the need for sand cores.

Other Technical Developments

Materials handling provides one of the most likely fields for increased mechanization, in that the movement and manipulation of a large volume of materials are characteristic of foundry operations. In jobbing foundries, in which mechanization is ordinarily limited, the moving of lighter materials, such as small molds and cores, is usually accomplished by means of simple lifting and carrying or by hand-operated trucks; large molds and other heavy or bulky objects are transported by overhead and side-wall cranes. Production operations make use of a variety of materials-handling devices, including electric tractors and lift trucks and, in the more highly mechanized establishments, of extensive belt and overhead conveyor systems. Stimulated by wartime labor shortages, the long-run trend toward installation of materials-handling equipment has gathered momentum.

In the cleaning, chipping, and finishing phases of the foundry process, mechanization has made substantial advances. The newer tumbling machines and blasting apparatus, which raise the efficiency of the cleaning operations, will be more extensively installed. Quicker finishing is provided by the growing use of improved grinding apparatus.

Modern furnace equipment and the wider use of conveyor systems in charging the furnaces increase the rate of melting operations. Efficiency in melting is also raised by greater use of duplexing and triplexing, in which several types of melting units are successively used.

Technological developments tending directly to increase foundry employment include extension of the use of heat treatment and intensifying inspection and quality-control procedures.

Heat-treating procedures improve the physical qualities of castings and provide a desired range of mechanical properties. The principal processes employed include annealing, normalizing, quenching, tempering, and flame hardening. Although one or more of these methods is applicable to most of the casting metals, the most important use has been in the making of malleable-iron and steel castings. However, heat treatment of gray iron has increased markedly during recent years.

Many elaborate devices and techniques have been developed to aid in inspecting the mechanical properties and internal structure of cast metals. The more important types include radiography, magnetic methods, and pressure tests.

EFFECT OF TECHNOLOGICAL CHANGES ON FOUNDRY EMPLOYMENT

Man-hour output varies widely among foundries, reflecting the diversified nature of cast products, the distinction between jobbing and production methods, the differences between the smaller and the larger establishments, and the inevitable lag between the introduction of new methods and their widespread application. There is, nevertheless, a marked trend toward increased output per man-hour.

During the war, the high volume of castings production, the improved financial position of many foundries, and the continuing shortages of workers resulted in rapid and extensive advances in the substitution of machine methods for hand processes. Sales of foundry equipment—including molding and coremaking machines, new melting units, and cleaning and finishing apparatus—reached unprecedented levels. Much more use was made of centrifugal casting, permanent molds, and other quantity-production techniques. However, output per man-hour showed little increase in foundries as a whole; a greater weight of castings was produced with relatively fewer workers, but this was achieved mainly by lengthening working hours. The scarcity of skilled workers and the lack of efficient unskilled labor largely canceled out the immediate advantages of mechanization. Nevertheless, with the return of normal operating conditions, the large volume of labor-saving equipment installed, and the new methods applied will affect the levels of foundry employment.

In the long run, technological developments will lead to a gradual reduction in foundry employment in relation to the output of castings. These effects will be variable. Jobbing operations are by their nature susceptible to only limited mechanization; in quantity production, a more marked decrease in labor requirements is probable. In relation to the end uses of castings, this will eventually mean that the greatest relative reductions in employment will occur in foundries serving the mass-production industries, such as those making automobiles, plumbing and heating equipment, and household appliances; the labor force in establishments making castings for limited-quantity uses, such as machine tools and special-purpose machinery, will be less affected. Thus, the general level of foundry employment will depend upon the nature, as well as the magnitude, of the demand for castings.

One additional factor may be noted. If lower production costs, resulting from technological developments, lead to an expansion in the markets for castings, then increased output per man-hour may partially offset its own tendency to reduce employment.

It is also necessary, in evaluating the effects of technical progress on foundry employment, to consider the relative importance, in terms of employment, of the various foundry operations. Molding departments are most important, accounting for roughly 30 percent of all production workers in foundries. Coremaking employs about 10 percent of the total. As noted, these departments are subject to substantial mechanization, not only of direct molding and coremaking processes, but also of many incidental handling operations. Cleaning, chipping, and finishing account for nearly a fifth of the foundry workers. Requirements for unskilled labor in these processes gradually will be reduced, particularly in connection with materials handling. Labor requirements in melting operations eventually will show a moderate decline, but foundry employment as a whole will be little affected by changes in this relatively small department. Greater use of testing apparatus and other quality controls and more extensive application of heat treatment will increase employment in the numerically small inspection and heat-treating departments.

Employment Outlook

The outlook for foundry employment depends upon the prospective trends in foundry production and technology.

In the immediate postwar years, the levels of foundry employment will be determined primarily by the volume and type of castings produced; technological change, typically a gradual process, will be a less-important factor. During this period, foundry activity as a whole will be at a very high level. However, production of gray-iron and malleable-iron castings is likely to be greater than the peak wartime output, and that of steel and nonferrous-metal castings considerably below.

In addition, there will be a shift in the nature of the markets for castings. The anticipated high volume of consumer durable-goods output and the expected increase in construction, both of which will contribute greatly to the total demand for castings, will require mainly the types of castings produced in large quantities. Castings for machine tools and other limited-quantity purposes will be relatively less important. Emphasis will thus be placed on the types of foundry operations in which output per man-hour is comparatively high, a development tending to reduce total requirements for foundry workers.

The effects of extensive mechanization of foundry operations during the war will carry over into the postwar period, but should not of themselves result in any immediate marked decrease in employment. A much more important factor is the probable return to about a 40-hour workweek, causing a substantial increase in the relative employment requirements of foundries.

Taking into account production prospects, technological factors, and the probable reduction of working hours, it appears that total employment for foundry workers during 1947 and 1948 will be slightly above the estimated number in July 1945 (when the initial cut-backs in war production had already been felt). The total foundry employment anticipated for 1947–48 is somewhat lower than the 1944 peak, but far above the 1939 level. Increases are indicated for gray-iron and malleable-iron foundries, and decreases for steel and nonferrous foundries.

The forecasts for 1947–48 are compared with estimated employment in 1939, 1944, and July 1945 in table 4.

TABLE 4.—*Estimated Foundry Employment* [1] *in Selected Periods*

Type of foundry	Estimated number of production workers			
	1939	1944	July 1945	1947–48 (average)
All foundries	255,000	425,000	375,000	360,000–395,000
Gray-iron, including cast-iron pipe	150,000	160,000	155,000	185,000–200,000
Malleable-iron	30,000	40,000	37,000	50,000– 55,000
Steel	40,000	100,000	78,000	70,000– 75,000
Nonferrous-metal	35,000	125,000	105,000	55,000– 65,000

[1] Estimates include workers in both captive and independent foundries and are based on current product classification; therefore, they cannot be related to the published foundry-employment series of the Bureau of Labor Statistics, which cover only independent foundries and are based on 1939 product classification.

In the longer run, say the 5- or 10-year period beginning about 1950, total foundry employment will probably show a moderate decline from the immediate postwar level, but will remain well above 1939, if general business conditions are favorable. After the accumulated demands for certain durable goods have been met, the distribution of employment among the major classes of foundries will tend to return to the prewar pattern. For this reason, employment in gray-iron and malleable-iron foundries, greatly expanded in the immediate postwar period, will probably be reduced. On the other hand, employment in steel castings, having been sharply deflated in the first peacetime year, will tend to remain fairly stable;

employment in nonferrous casting, after the initial postwar drop, will show a gradual moderate rise.

In the long run, technological developments will become a highly significant factor affecting employment. There will be a gradual but steady increase in castings output per man-hour which, in a period of stable or declining output, will lead to further reductions in employment. There is also the possibility that the rivalry between casting and alternative methods of fabrication may result in some net loss of foundry markets.

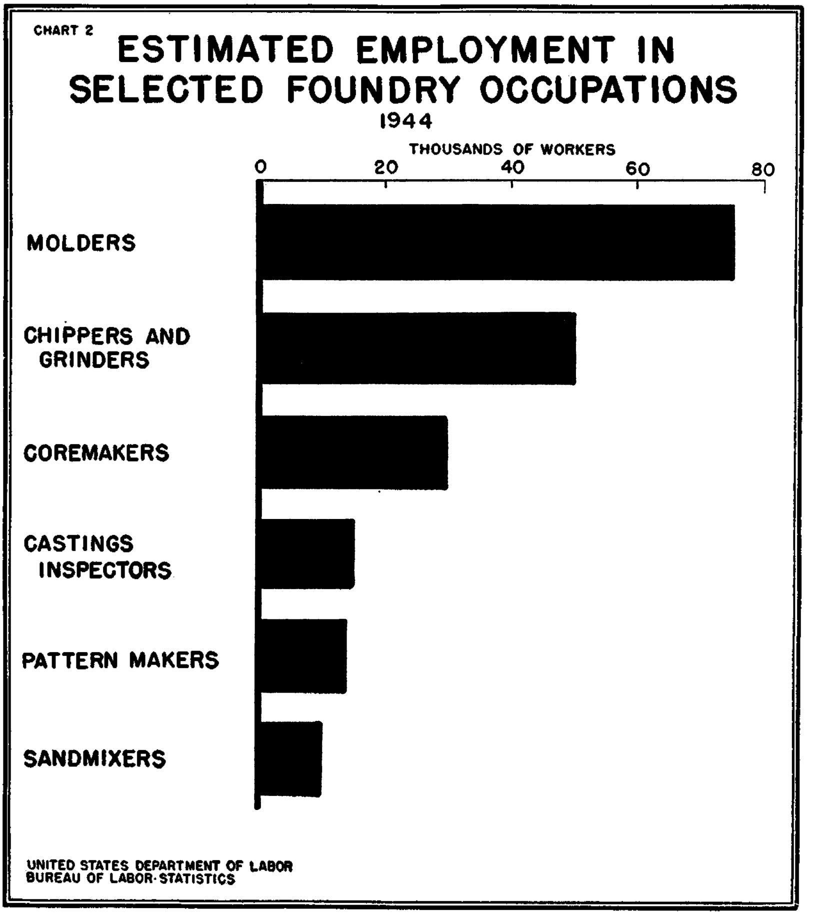
There is no indication, however, that this gradual decline in foundry employment from the high levels of the immediate postwar period, which may continue over a period of many years, will result in the loss of jobs for any significant number of foundry workers, although the number of openings for new workers will be diminished.

Because of such factors as the extent to which workers can readily transfer from one type of foundry to another, the replacement demands resulting from death, retirement, and labor turn-over, and the demand and supply affecting individual occupations, information on the trend of total foundry employment does not of itself provide an adequate basis for appraisal of the opportunities for employment in foundries. The second part of this study of the employment opportunities in foundry occupations will relate the changes in employment here noted to the employment opportunities in specific occupations.

Part 2.—Outlook in Foundry Occupations

General Characteristics of the Foundry Labor Force

Foundries constitute one of the most important fields of employment for trained workers in manufacturing. Of the estimated 425,000 production workers employed in foundries in 1944, over one-fourth might be classed as skilled. Most of these skilled jobs, as well as many of the less-skilled, are peculiar to foundry processes—molding and coremaking, particularly. Estimated employment in 1944 in some of the more important types of foundry work is shown in chart 2.[1]



[1] These estimates are based mainly on data obtained from occupational wage-rate surveys of the Bureau's Wage Analysis Branch and on unpublished Selective Service occupational registration data for 1942–43, adjusted for under-coverage and for the increase in foundry employment between 1942–43 and 1944. There is, of course, some discrepancy between the estimate of 75,000 employed molders in 1944 and the number reported as of March 1940 to the Census. The Census counted 75,904 employed, at a time when foundry employment was considerably less than in 1944. It is probable, however, that the Census figures are inflated by the inclusion of a large number of foundry workers other than molders. The smaller total is therefore better suited to the purpose of this study.

There are of course many other occupations represented in foundries, including maintenance workers (such as carpenters and electricians), a large number of laborers, and office and professional employees. These jobs are not characteristic of foundry work as such and are not, therefore, discussed in this study. Their outlook may be judged in the light of the prospects for foundry employment as a whole.

The foundry occupations are mainly limited to men, reflecting the strenuous nature of much of the work, as well as certain traditional employment practices. In 1939, less than 1 percent of the production workers in independent foundries were women. (The proportion of women in captive foundries was probably but little higher). During the war, a considerable increase in the utilization of women in foundries occurred, but not enough to change greatly this feature of foundry employment. In general, foundry work remains primarily a man's job.

The proportion of Negroes in foundries is markedly high: in 1944, they constituted more than one-fourth of all production workers in independent ferrous foundries. They are employed not only in many unskilled and semiskilled foundry occupations but also to a substantial extent as skilled molders and coremakers. In March 1940, Negroes comprised about 8 percent of the employed molders reported in the Census of Population.

Wages in foundries compare favorably with those in the basic metal industries generally. Shown below are average gross hourly earnings in independent ferrous foundries, compared with earnings in the entire group of industries producing iron and steel and iron and steel products, excluding machinery.

	1939	*1945*
Gray-iron foundries	$0.70	$1.10
Malleable-iron foundries	.67	1.10
Steel foundries	.76	1.14
Cast-iron pipe foundries	.58	.91
Iron and steel industry group	.74	1.10

These data reflect overtime, night-shift, and other premium pay, and do not therefore provide a full comparison of straight-time earnings. In addition, the increases shown between 1939 and 1945 result in part from upgrading and other changes in the occupational structure. In the subsequent treatment of specific foundry occupations, average straight-time earnings are presented for each occupation for which such data are available. The table on page 55 shows earnings by occupation in 14 selected localities.

Among the many types of jobs associated with foundry work, three occupations—molder, coremaker, and patternmaker—stand out as especially significant. Molding and coremaking are relatively large occupations and include a high proportion of skilled jobs requiring apprenticeship or equivalent training. Although fewer workers are engaged in patternmaking, the skill needed is very high and apprenticeship is the normal method of entry. Duties, qualifications and training, employment prospects, and earnings for each of these three categories, as well as for certain other types of foundry jobs, are discussed below. The descriptions of the work in these occupations are not only intended to provide a general picture of the operations but are also designed as a basis for understanding the analysis of trends in supply and demand for each kind of job. Only the more commonly used production methods are discussed and the less important details of the work are omitted.

Employment Outlook for Molders

The primary function of molders is to prepare the sand molds in which metal is cast. Basically, this involves packing sand around a model ("pattern") of the desired object and then withdrawing the pattern, leaving in the sand a hollow space, or "mold cavity," in the shape of the casting to be made. The specific duties of molders, however, vary widely according to the type of operation. These differences greatly affect skill requirements and assume considerable significance in relation to employment prospects.

The Work of the Molder

ALL-ROUND HAND MOLDERS

The essential features of all-round hand molding, which distinguish it from other types of molding, are that it involves the making of widely varying kinds of molds and that it requires workers of journeyman qualifications who use mainly hand methods and perform nearly all the steps in the process.

Bench molding and floor molding are the two principal divisions of hand operations. In bench molding, small molds are prepared on work benches. In the various types of floor molding, larger molds are constructed on the foundry floor.

Bench molding.—The bench molder first assembles the pattern to be used and a suitable molding box, or "flask," on his work bench. He places the lower ("drag") half of the molding flask upside down on a flat molding board and sets the lower half of the pattern (if a two-part pattern is used) in an inverted position on this board. If his duties include determining the most efficient placing of the pattern, he must be able, at this point, to visualize the entire casting process. Frequently, however, this decision is the responsibility of a supervisor.

After placing the pattern, the molder fills the flask with molding sand, covering the pattern. Using hand-ramming tools, he compacts the sand around the pattern, employing considerable skill to obtain a proper and uniform degree of density. Setting a flat board on top of the mold, he rolls the mold over and exposes the lower half of the pattern. He joins the upper ("cope") half of the pattern to the lower part, and places the cope half of the flask on the drag. Using the top surface of the drag of the mold as a base, he prepares the upper (cope) section of the mold in much the same manner as he made the drag half.

Following this operation, the bench molder cuts a channel, or "sprue" (through which the molten metal will later be poured), leading from the top surface of the mold to a point near the embedded pattern. He separates the mold sections by lifting the cope mold from the drag half, and then very carefully takes out the pattern sections from the sand. This phase of molding requires a high degree of skill in order to avoid serious damage to the mold impression and to patch by hand any minor damage resulting from pattern withdrawal.

The molder's next step is to "gate" the mold, that is, to cut passages in the sand connecting with the sprue, or feeding channel. Determining the most efficient arrangement of these passages, which provide for the distribution of molten metal within the mold, also requires skill of high order. However, a foreman may provide general instructions on how this work is to be done or gated patterns may be used, greatly simplifying the whole operation.

The final steps in the molder's work are to apply a facing material, such as graphite, to the mold cavity in order to strengthen it; to set the sand cores (which will form any hollow spaces needed in the casting) into place within the mold; and to reassemble the mold sections. In some small foundries, he may himself pour molten metal into the completed mold. More commonly, however, pouring is done by other workers, although often under the molder's direction.

Floor molding.—The work is much the same as bench molding, with certain exceptions, some of the more important of which are as follows: A crane or hoist is used to turn over the mold sections and to withdraw large or bulky patterns, with the crane operator working according to hand signals from the molder. The floor molder reinforces the structure of the mold by inserting metal rods ("gaggers") and nails into the sand at the appropriate points which he selects. Pneumatic rammers are substituted for hand tools in compacting the sand. One or more helpers may ram the sand, bring up materials, and assist the floor molder in other ways.

Pit and sweep molding.—Other all-round hand-molding jobs, less common than either bench or floor work, are pit molding (in which large molds are constructed within a pit in the foundry floor) and sweep molding (in which the mold cavity is formed by moving a shaped board, or "sweep," over a bed of sand).

LESS-SKILLED HAND MOLDERS

All-round hand molding of the types described above is characteristic of limited-quantity (jobbing) operations. In the making of molds which are required in very large quantities, but which are unsuited by reason of their size or shape for machine molding, hand molders without diversified qualifications are frequently employed. This type of worker prepares the single type of mold which he has learned to make. Although the mold itself may be quite intricate, the job is greatly simplified because it is repetitive. The less-skilled molder often performs all the steps of making a mold, but a journeyman molder must be provided to supervise groups of these workers. The exercise of judgment in such operations as gating and finishing the mold may be delegated to this supervisor. In another type of molding method, gating and finishing are performed by qualified molders, called "mold finishers," employed for this specialty, and molds up to but excluding these final and more difficult steps are prepared by less-skilled molders.

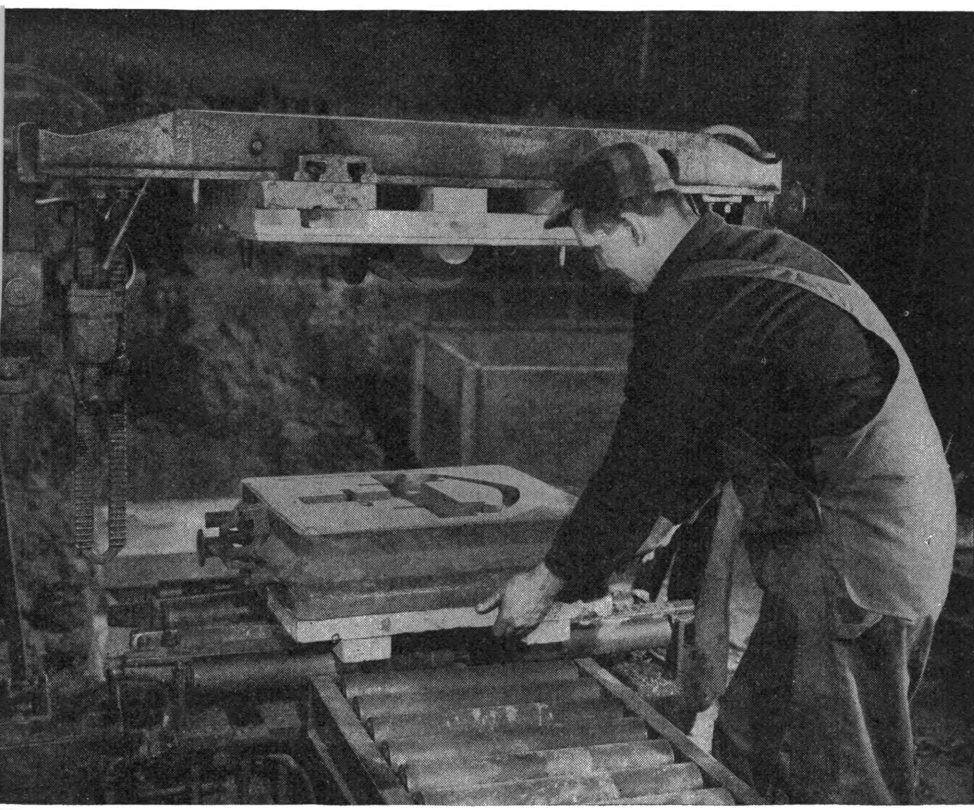
In still another type of hand operation, large molds are prepared by a crew, or "gang," of 10 or 12 men headed by an all-round molder. Each of these workers performs a set of specialized duties, such as ramming, under the molder's direction. There may be, in addition, a separate crew which is responsible for the final finishing of each mold.

MACHINE MOLDERS

Machine molders operate one of several types of machines which simplify and speed up the making of a large quantity of identical molds. Each of the various types of machines (briefly described in Part 1 of this study) substitutes mechanical operation for one or more of the major steps involved in hand molding, and accordingly reduces the skill required. Machine molders are differentiated on the basis of the functions of the machines that they use.

Molders using simple squeezer, jolt and jar, or roll-over molding machines may perform nearly all the skilled duties of hand molders. However, these machines, and especially the squeezer, are very commonly used in conjunction with mounted patterns and mechanical pattern-withdrawal devices. This combination eliminates from the operator's work such important steps of hand molding as positioning the pattern, hand cutting the gates, and aligning cope and drag sections of the pattern and mold. Sand-slinger machines are operated by semiskilled specialists, not properly classed as molders since they perform no other steps in molding.

The basic duties of a machine molder consist mainly of assembling the flask and pattern on the machine table, filling the flask with sand, and actuating the machine by the properly timed use of its control levers and pedals. Any additional duties of a machine molder are determined by his qualifications and by the manner in which the molding department is organized in the foundry in which he works.



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Machine Molding.

The operator of a molding machine may be a qualified journeyman molder who requires little supervision, in which case he sets up and adjusts the machine for each job, sets cores, and gates and finishes his own molds. More commonly, however, the machine molder lacks these skills, so that his duties are limited mainly to operating the machine, which another worker, either a qualified molder or a maintenance employee of the foundry, adjusts for him. Skilled mold finishers receive the partly completed molds as they come from the machines and perform the finishing operations.

Qualifications and Training

A 4-year apprenticeship, or its equivalent in on-the-job training, is normally required to qualify as an all-round (journeyman) molder.

The molder apprentice works under the close supervision of journeymen who instruct him in the skills of the craft. About half of the apprenticeship training is devoted directly to molding. Working closely with a journeyman molder, the apprentice begins with simple tasks, such as shoveling sand, and gradually takes on more difficult and responsible work, such as ramming molds, withdrawing patterns, and setting cores. He also learns to operate the various types of molding machines used in the foundry. As his training progresses, he makes complete molds, under supervision, beginning with simple shapes and going on to those of increasing complexity. This molding phase of his apprenticeship includes both floor and bench work, and qualifies him for both branches of molding.

In addition to his time spent in learning molding, the apprentice works in other foundry departments in order to develop the diversified knowledge of foundry practice needed by fully qualified molders. He learns sand preparation, melting of metal, and the cleaning and finishing of castings. For a brief period, the apprentice serves in a pattern shop as a helper. He spends considerable time in the coremaking department, and, under many apprentice programs, gets sufficient training to qualify as a skilled coremaker.

The apprentice usually receives, in addition to his shop work, at least 144 hours of classroom instruction each year in such subjects as shop arithmetic, metallurgy, and shop drawing.

It is also possible for a man to develop journeyman skill without apprenticeship or similarly organized form of learning on the job. Molders' helpers and less-skilled hand molders sometimes succeed in acquiring informally the various elements of skilled molding, and then seek jobs as journeymen. However, this is a lengthier and less reliable way of learning the trade than apprenticeship. A helper in some cases may advance to journeyman status by transferring to an apprentice classification, with his previous experience as a helper credited toward the apprenticeship period.

Full-time 1- or 2-year trade-school courses in molding are available in many localities. If the school's equipment is adequate and its instruction of good quality, useful preparation for the molding trade may be provided, in that the trade-school course may be credited toward completion of the molding apprenticeship. However, these schools cannot qualify their students for jobs as journeymen molders without an additional period of work experience.

The less-skilled type of hand molding, in which highly repetitive work is done, requires only a brief training period. "Learners" (either men without previous foundry experience or upgraded foundry helpers) are assigned to work with a molder engaged in making a particular kind of mold. After 2 to 6 months of this training, the learner is usually competent to make the same mold, or one that is roughly similar, on his own responsibility.

For machine-molding jobs of the more difficult and responsible types, a molding apprenticeship or equivalent training is required. However, machine molding of the less-skilled variety, in which close supervision is provided and finishing is delegated to other workers, is ordinarily learned in 60 to 90 days of on-the-job training.

A molder apprenticeship, or its equivalent, is usually needed to qualify for supervisory jobs and for the skilled specialties, such as mold finishing.

In the past, educational requirements for molders have not been high. Seventy-five percent of the molders (including machine molders) reported in the 1940 Census of Population had no more than a grade-school education. However, educational standards for entry into the occupation have been gradually raised. For a molding apprenticeship, an eighth-grade education is usually the absolute minimum, and many employers specify additional school work up to and including high-school graduation. Eighth-grade schooling, however, still suffices for most jobs as learners of specialized hand or machine molding.

Physical standards for molding jobs are fairly high, taking into account the needs for continual standing and moving about, frequent lifting, and good vision. For hand molding, a high degree of manual dexterity is essential. Since the work is fairly strenuous, even in many kinds of machine molding, very few women are employed as molders.

Employment Outlook

During the next few years, a strong demand for molders will be maintained if the anticipated high rate of foundry activity is realized. Although foundry employment as a whole will be slightly below the 1944 peak (on the basis of the estimates made in Part 1 of this study), the number of molders' jobs should approximate that of 1944—when about 75,000 molders were employed. This is explained by the differences in employment outlook among the major classes of foundries and in their relative utilization of molders. It is expected that gray-iron foundries, in which the ratio of molders to other workers is comparatively high, will substantially expand employment in 1947–48 over their wartime requirements. On the other hand, the postwar drop in aluminum and magnesium casting, accounting for much of the anticipated decrease in foundry employment generally, will not greatly affect the total number of molders needed, since the ratio of molders to other workers in these foundries has been relatively low.

Although the general level of foundry employment constitutes the most important single factor affecting the outlook for molders, there are, in addition, a number of other considerations which influence employment prospects. These include the supply of molders, the probable volume of replacement demand, and technological developments affecting employment and skill requirements.

SUPPLY OF MOLDERS

In considering the number of persons likely to seek molding jobs it is necessary first to distinguish the various degrees of skill represented by those included under the general heading of "molder." As previously indicated, three fairly definite skill classifications emerge.

First, there are the journeymen molders, mainly employed in bench or floor molding in job foundries, but also used in supervisory or skilled specialist jobs in production operations. This is a relatively small group, and one to which few workers have been added during recent years. In the war period, the training of apprentices was restricted by the operation of the draft. Moreover, this curtailment followed a long period in which the training of molder apprentices was at extremely low levels, reflecting both the depressed condition of metalworking industries during the thirties and the long-run trend toward the mechanization of molding. The rapid wartime expansion of steel and nonferrous-metal casting spread thin the limited supply of journeymen molders, and necessitated the training of a large class of hand molders of specialized, more limited skill.

In spite of brief and specialized training, the less-skilled hand molders in many cases have greatly increased their skill and versatility in the course of their wartime experience. As a result, many of these workers will be able to get jobs as journeymen during a period in which the supply of all-round molders remains short, and thus will constitute a real addition to the skilled-molder labor force.

Machine molders (in the sense of workers qualified only as operators of molding machines, and excluding journeymen working at machine molding) have been increasing in number over a period of many years, reflecting the substitution of machine molding for hand operations and the gradual break-down of skilled jobs into less-skilled specialties. Wartime expansion of foundry production, as well as the scarcity of qualified journeymen, gave impetus to this growth of machine molding, which has, in turn, augmented the supply of experienced machine molders.

In evaluating the supply situation for molders, it is also necessary to consider the transferability of workers among types of foundries and among important foundry areas. In general, it is not difficult for a worker experienced in making molds for one kind of metal to shift to the making of a comparable type of mold for another metal. However, a short period of readjustment is usually required, especially in transfers between steel casting and gray-iron casting.

Wartime increase in the supply of molders has occurred mainly in the same general areas in which foundry work will be most important in the postwar years. In some communities within these areas, however, there has been a temporary oversupply of molders; in others, a shortage. Many molders, mainly the less-skilled, in the localites in which there is a surplus, have been reluctant to move to other cities and have gone into different types of work instead. As a result, there has been some net reduction in the total supply of molders.

Demobilization of the armed forces has not had any especially significant effect on supply, in contrast to the situation in certain other metal trades. Relatively few journeymen molders were drafted, since the large majority of these men were over military age. On the other hand, there is a somewhat larger group of younger and less-skilled men with some molding experience who have returned from military service. The services have trained few, if any, men as molders.

REPLACEMENT DEMAND

Owing to the relatively advanced age of the molding labor force, the replacement of those who die or retire should of itself provide an important source of demand for new workers in the next 5 to 10 years. In 1940, according to the Census of Population, the median age of employed molders was about 42 years, and 15 percent were over 54 years of age. On the basis of census age data, it is estimated that the average death and retirement rate for molders will exceed 1,500 annually between 1940 and 1950. Since many molders, like other workers, have postponed retirement during the war, the actual rate during the next few years will probably be somewhat greater.

However, the census age distribution and the resulting estimate apply to all types of molders. For the journeyman group alone a still higher replacement rate is indicated, since these workers are known to be considerably older, on the average, than the other categories of molders. On the other hand, wartime additions to the supply of molders below the journeyman level of skill have included mainly younger workers; and thus replacement demand owing to death and retirement should operate at a lower rate for this group.

Need for replacement is also created by the transfer of workers from foundries to other lines of employment. As few journeymen molders leave their occupations, not many jobs can be expected from this source. At the lower levels of skill in molding, however, moving to other kinds of work is a more important factor; for this reason, actual replacement requirements will exceed considerably the volume estimated on the basis of death and retirement.

TECHNOLOGICAL TRENDS AFFECTING EMPLOYMENT OUTLOOK

It was shown in Part 1 of this study that numerous and extensive technological developments have occurred in molding, and that these changes have tended to increase output per molder and, at the same time, to reduce the skill required. It has also been indicated that the long-run prospects are for continuation and intensification of this trend. These developments include, primarily, the greater use of machine molding, permanent molds, centrifugal casting, and improved pattern equipment. In addition, there is the possibility that investment casting will make some inroads into sand casting. During the next few years, the effects of these changes may not be substantial; over a longer period they will become a highly significant element in the outlook for molders, in that they will greatly affect the ratio of molders to other foundry workers and will thus in large part determine demand in this occupation. However, the mechanization of limited-quantity operations will proceed much more slowly; therefore jobbing foundries will continue to provide an important source of employment for all-round hand molders.

Another major technological development affecting occupational opportunities has been the substitution of semiskilled specialists for journeymen by breaking down the molding process into a number of specialized jobs. Owing to the shortage of all-round molders, this practice gathered momentum during the war and led to a significant reduction in the ratio of journeymen molders to other foundry workers.

In spite of the fact that actual skill requirements in molding have been and will continue to be reduced, the tendency will be to use journeymen molders for mechanized molding operations. The advantages of employing them for relatively specialized jobs are fairly substantial. As molding-machine operators, journeymen require a minimum of supervision. They can set up their own work, are able to shift readily from one type of mold to another, and can perform all the steps of finishing the molds made on their machines. In foundries where semiskilled specialists—hand or machine—continue to perform most of the operations in preparing molds, some journeymen will still be needed for supervisory jobs and for such skilled specialties as mold finishing. Even in permanent-mold casting, in which skill requirements are minimized, a few journeymen are required—some to supervise permanent-mold operations and others to cast the permanent molds which are used.

The impact of technological change will be greatest on the large groups of specialized hand molders trained during recent years. The types of molds made by these workers are most susceptible to the extension of machine molding and other mechanized methods.

The trend toward greater use of machine molding, tending to increase the number of machine-molding jobs, will be offset by improvements in machine molding which restrict employment gains by increasing output per worker.

EMPLOYMENT PROSPECTS FOR MOLDERS

Taking into account all important supply and demand factors,the future opportunities in molding, both for those now in the occupation and for those who may enter it, appear to be as noted below, for the various grades of molders.

(1) *Journeymen molders* will be in the best position. As a result of their present scarcity, their adaptability to mechanized as well as hand operations, and the anticipated volume of replacement needs, the demand for such molders should substantially exceed the supply for at least several years. Thus, employment opportunities for experienced journeymen should be plentiful, and there should also be numerous openings for newly trained journeymen. During the next 4 years, however, while young workers who now enter the occupation as apprentices are still in training, many specialized hand molders will probably succeed in rising to the journeyman level. Competition with this group will tend to limit somewhat the opportunities of the newly trained journeymen.

To the extent that journeymen molders are available, they will probably be hired for the less-skilled, but often well-paid, specialized jobs, as well as for all-round work. Moreover, supervisory positions in molding will continue to be filled from the journeyman ranks.

Opportunities for young workers to obtain molder apprenticeships should be numerous in the immediate future, reflecting the growing feeling among foundry employers that a revival of apprentice training is needed, in view of the depleted supply of journeymen. In addition, apprenticeship will probably be expanded under the veterans' training provisions of the GI Bill of Rights.

In the longer-run period, the anticipated gradual, although moderate, decline in foundry activity from the high levels of the immediate postwar years, combined with rising output per man-hour in molding as a result of technological change, will reduce the number of jobs for journeymen molders. At the same time, expanded apprentice training and upgrading may relieve the formerly short supply of journeymen. However, in view of continuing deaths and retirements, the drop in demand should not be sharp enough, nor the probable increase in supply sufficiently great, to cause unemployment of workers already established as journeymen molders.

(2) *Less-skilled hand molders* with experience have favorable employment prospects for the immediate future, although much less so than journeymen. The number of such jobs will be slightly below the wartime peak, but demand and supply will probably be roughly balanced, since some of these less-skilled workers have transferred to other lines of employment. For several years there will be openings for a limited number of men without previous experience in molding. However, the number of these opportunities will be very greatly diminished when and if fully qualified molders become available.

Continuing technological developments and the possible increase in the supply of journeymen in the long run may seriously curtail employment opportunities for those who remain at this skill level. However, such workers—and there will be many—who succeed during the next few years in acquiring the necessary broad experience will compete on roughly even terms with the newly trained journeymen.

(3) *Operators of molding machines* with experience have immediate employment prospects roughly comparable to those of the less-skilled hand molders. Although the actual number of machine-molding jobs is expected to be slightly below the wartime level, withdrawals from the occupation have reduced the supply, permitting the absorption of a limited number of new workers.

In the longer run, employment in machine molding should be fairly stable, although most vacancies for these jobs will be filled by journeymen molders if enough are trained. However, the future growth of machine molding will provide continued employment for the more experienced and efficient of the operators, even though they may not be qualified as journeymen.

Earnings [2]

Molders are among the best-paid foundry workers. In January 1945, average straight-time hourly pay in independent nonferrous-metal foundries was $1.35 for floor molders, $1.22 for bench molders, and $1.29 for machine molders. In independent ferrous-metal foundries (excluding cast-iron-pipe foundries) average straight-time earnings were $1.17 for floor molders, $1.14 for bench molders, and $1.31 for machine molders. Hourly earnings in "captive" (integrated) foundries of the machinery industries averaged $1.15 for floor molders,

[2] Earnings data shown in this study are in summary form. Detailed information on earnings in independent foundries is obtainable from the Bureau's Wage Analysis Branch. Local summaries are available for selected cities of 100,000 or more; regional and national summaries are provided in two mimeographed reports, (1) Wage Structure: Foundries, 1945, and (2) Occupational Wage Relationship: Foundries, 1945.

$1.10 for bench molders, and $1.19 for machine molders. The above rates are for males only; female machine molders, of whom there was a small number, received considerably less. The higher averages shown for machine molders reflect mainly the fact that most of these workers are on incentive pay. The beginning rate for molder apprentices is usually between a third and a half that of journeymen.

Employment Outlook for Coremakers

Coremakers prepare the bodies of sand, or "cores," which are placed in molds to form hollows or holes required in metal castings. (Molten metal flows around the core, and when the core is later removed the desired cavity is left.) In this occupation, as in molding (to which coremaking is closely related), hand and machine operations are the two divisions.

The Work of the Coremaker

HAND COREMAKING

The duties of hand coremakers vary considerably according to the size and complexity of the cores they make. In addition, there are distinctions between bench and floor work (as in molding) and between "dry-sand" and "green-sand" coremaking.

The simplest type of coremaking consists of preparing small, one-piece, dry-sand cores or core sections. For this work, a one-piece core box is used. The core box is simply a block of wood or metal into which a hollow space of the size and shape of the desired core has been cut. The coremaker fills the hollow with sand and packs the sand to the desired degree of density. He turns the box over, placing it on a flat metal core plate. Then the coremaker loosens the shaped core from the core box by gently rapping the core box with a mallet. When the core plate is filled with cores, it is transferred to a core oven, and the cores are baked until they are sufficiently hard.

These operations are essentially routine, especially when a very large number of identical cores are made, and persons with a narrow range of specialized skills are usually employed. The preparation of large or intricate cores is a more difficult and intricate process and requires a coremaker with broader knowledge and experience.

In the making of complex cores, the coremaker uses a core box with two or more sections, each section forming a part of the core. First, the coremaker partially fills one section of the core box with sand. After carefully ramming this sand, he reinforces it by inserting wires or rods. In order to lighten large cores and to permit the escape of gases formed in casting, he may place a layer of cinders or coke at the center of the core. Then he completely fills the core box with sand and rams it to the proper density. He may provide gas vents by piercing the core sand with wires or he may cut a small V-shaped trough in the sand, which, when the core sections are assembled, will form a narrow passage.

After reinforcing and venting, the coremaker withdraws the core from the core box, taking special care to avoid damaging complex core designs. Any damage to the core's shape resulting from withdrawal he patches by hand. In dry-sand coremaking, when all the sections have been prepared, they are transferred to an oven for baking. In green-sand coremaking, baking is omitted. The coremaker may be required to control the baking process, or this task may be given to a specialized "core-oven tender." The baked core sections are assembled by pasting. If the core assembly is complex, pasting is usually done by the coremaker. (Less difficult core assemblies are prepared by a semiskilled "core paster.")

PHOTO BY U. S. DEPARTMENT OF LABOR

Bench Coremaking.

MACHINE COREMAKING

Machine coremakers operate one of the various types of coremaking machines described in the first part of this study. In general, these machines, used in the production of a large number of identical cores, mechanically perform one or more of the steps needed in hand-coremaking, and thus reduce the skill required of the worker. Coremaking machine operators are classified according to the kind of machine that they use.

Coremaking by means of the turn-over (or "roll-over") draw machine eliminates hand work in connection with ramming of the sand and withdrawing the core, and to this extent reduces skill requirements. Fully qualified coremakers using turn-over draw machines require little supervision. They set up their machine for each job, do any necessary reinforcing and venting, and smooth the cores as they come from the machine. Less-skilled workers must be more closely supervised and the necessary adjustments of the machine made for them. Since these specialized operators make less intricate cores, reinforcing, venting, and other tasks involving judgment are considerably simplified. Actual operation of the turn-over draw machine requires placing a core box on a machine table, actuating the machine by the properly timed use of hand- and foot-operated controls, and transferring the completed core from the machine to a core plate.

In coremaking by means of the die (or "extrusion") type coremaking machine or the core blower, the main duties of workers are those of relatively routine machine tending. Skill levels in these operations depend on whether or not the worker is required to set up his own machine for new jobs.

Qualifications and Training

For all-round coremaking, involving hand work on varying types of intricate cores, and for most supervisory jobs in coremaking departments, the journeyman level of skill is required. Journeyman status in coremaking is achieved through completion of an apprenticeship, customarily of 4 years, or the equivalent in other on-the-job training.

Coremaker apprenticeship is very frequently combined with the training of molders in a single molder apprenticeship, and, in this sense, molding and coremaking constitute branches of one occupation. In many cases, all-round coremakers are drawn from among those who have completed a molder apprenticeship in which extensive coremaking training was included and who chose coremaking, rather than molding, as their journeyman specialty. However, there are separate coremaker apprenticeships provided in many foundries.

The coremaker apprentice works with journeymen coremakers, first helping them in routine duties and then undertaking more advanced work under close supervision, such as making simple cores, operating core ovens, and pasting cores. As his skill increases, the apprentice makes more complex cores. He receives experience in bench and floor work, in dry-sand and green-sand coremaking, and in the operation of any coremaking machines used in the foundry. A substantial part of this apprentice period is devoted to molding, sand preparation, melting, and other phases of foundry work in order to provide the necessary background for all-round coremaking. Like other apprentices, the apprentice coremaker normally receives at least 144 hours of class-room instruction each year, covering such subjects as arithmetic, shop drawing, and properties of metals.

Some semiskilled coremakers, helpers, and other core-room workers manage to acquire journeyman status without an apprenticeship. In general, however, apprenticeship or an equivalent training program is the main route to the job of all-round coremaker.

Courses in molding, coremaking, or general foundry work in the better equipped trade schools may serve to shorten the apprentice period for their graduates, but are not considered a substitute for on-the-job training.

A very brief learning period—sometimes less than 30 days—is needed for simple, repetitive coremaking. Persons without previous foundry experience may be hired as trainees, or foundry helpers or laborers may be upgraded to this work.

For machine coremaking, training requirements vary considerably. Journeyman skill or the equivalent is needed for the more difficult and responsible machine coremaking jobs, such as that of making, with little supervision, relatively intricate cores of varying types on the turn-over draw machine. On the other hand, the operation of coremaking machines, under close supervision, in the preparation of simple cores can be learned in less than 90 days.

Physical requirements for light coremaking, either by hand or machine, are fairly modest, since the work is not especially strenuous. A high degree of manual dexterity, fully equal to that needed in molding, is necessary for hand work. Women are frequently employed in this type of coremaking. The physical standards for work on heavy cores are roughly comparable to those for molding.

Employment Outlook

A strong demand for coremakers is in prospect for the next few years on the basis of the anticipated high volume of foundry employment. Although coremaker employment will be slightly below the wartime peak—about 30,000 were employed in 1944—it should far surpass the 1939 level. This will result from the probable expansion of gray-iron and malleable-iron foundry employment, largely offsetting the postwar drop in steel and nonferrous casting employment. In addition, however, to the probable volume of employment, it is necessary to consider supply, replacement, and technological factors in evaluating employment prospects.

SUPPLY OF COREMAKERS

Journeymen coremakers constitute a relatively small group. In recent years, the number of all-round coremakers has declined somewhat, reflecting the increased use of machine methods (and the substitution of semiskilled specialists), as well as the lack of active apprenticeship programs. During the war, the greatly increased demand for coremakers led to the upgrading of some less-skilled workers and to a limited revival of apprentice training. However, the number of fully qualified coremakers was not materially increased.

Wartime expansion of nonferrous and steel casting, especially the former, required the training of a large number of semiskilled coremakers (including a high percentage of women) to perform routine hand or machine work in making large quantities of light, simple cores. Some of these less-skilled workers have transferred to different lines of work, particularly when coremaker jobs were not available in their own communities and when moving to other cities was required in order to obtain this type of employment. Although this has resulted in some reduction in the supply of semiskilled coremakers, the total number trained and available still greatly exceeds the prewar total.

REPLACEMENT DEMAND

Although age data for coremakers are not available, it is believed that the average age of journeymen is relatively high, as a result of the long period during which there was little apprentice training. In view of this, it is expected that there will be a high rate of withdrawal from the trade, due to death and retirement, during the next few years. However, since journeymen coremakers constitute a relatively small group, the actual number of men needed as replacements in any one year is limited.

The replacement situation is different for the semiskilled group. These are mainly younger workers, and the rate of withdrawal, apart from transfers to other occupations, will probably be low for many years.

TECHNOLOGICAL FACTORS

Prospects are for the continued mechanization of coremaking operations along the lines indicated in Part 1 of this study. However, as has been previously shown, this process of substituting coremaking machines for the hand skills of the trade will for at least several years be limited mainly to the quantity production of the smaller and less intricate cores. Since journeymen coremakers are used primarily for work to which machine methods are often not adapted, the greater use of coremaking machines should not substantially affect their employment opportunities in the near future. In the longer run, however, a significant reduction in journeyman employment may result from continued technological change. Increased mechanization will more directly affect semiskilled hand coremakers, since this type of coremaking is often suited to the extension of machine methods.

The growing use of coremaking machines will tend to expand the total of machine-operating jobs. However, since the newer machines also increase output per man-hour, the actual number of jobs may not be materially increased.

Greater mechanization of coremaking, although tending to decrease employment of journeymen in hand operations, will, on the other hand, create some demand for journeymen in supervisory positions.

EMPLOYMENT PROSPECTS FOR COREMAKERS

The conclusions formed from the foregoing analysis are given below in terms of employment outlook for experienced coremakers as well as for prospective entrants into the field.

(1) During the next few years the demand for *journeyman coremakers* should exceed the supply, providing enough jobs in most foundry areas for experienced journeymen and a number of openings for new workers. Many apprenticeships should be available, reflecting the increased popularity of apprentice training among foundry employers and the stimulus which the GI Bill of Rights will probably give.

Promotions to supervisory positions in coremaking departments, whether hand or machine methods are used, will go mainly to qualified journeymen. In addition, journeymen will be used for the more difficult and responsible machine-operating jobs.

In the longer run, after the accumulated demand for castings for civilian products has been met and technological change gathers momentum, there will be some contraction of journeyman employment. However, this decline should not be rapid enough to displace journeymen already well established in the trade. Moreover, increased mechanization may well be accompanied by greater use of journeymen as machine operators. Of course, the number of openings for new workers will drop sharply.

(2) Opportunities for *semiskilled hand coremakers* will be moderately favorable for experienced workers but relatively poor for new entrants. Although the number of such jobs will be well below the wartime peak, this reduction has been offset by withdrawals from the occupation. Openings for trainees will be limited mainly to replacement needs. Increasing mechanization gradually will reduce the employment of these workers but the more experienced and efficient will probably have a permanent place in foundry work.

(3) The number of jobs for *machine coremakers*, although slightly below that of the war years, is expected to remain fairly stable for some time. During the next few years, experienced machine operators will be able to get jobs in most foundry areas. There will also be openings for men to train for this type of work. In the long run, opportunities will be somewhat restricted by the anticipated slight decline in foundry employment as a whole. In addition, some machine-operating jobs may be filled by journeymen coremakers if enough become available. However, it is probable that the bulk of experienced and competent operators will continue to have employment.

Earnings

The pay of coremakers is similar to that of molders. Male hand coremakers in January 1945 averaged straight-time hourly earnings of $1.22 in independent ferrous foundries (excluding cast-iron pipe foundries), $1.24 in independent nonferrous foundries, and $1.15 in captive foundries of the machinery industries (excluding the machine-tool, machine-tool accessories, and electrical machinery industries). Men operating turn-over draw machines averaged $1.26 in independent ferrous foundries, $1.29 in the independent nonferrous industry, and $1.33 in the machinery captive foundries. The incentive pay basis for much machine coremaking accounts in part for the higher earnings shown for the machine operators, most of whom are less skilled than the hand coremakers. Women in these occupations earned, on the average, substantially less than men.

As in molding, apprentices for coremaking typically start at from one-third to one-half of the journeyman rate.

Employment Outlook for Patternmakers

Patternmakers are the highly skilled craftsmen who construct patterns and core boxes for castings. This work is done in specially equipped pattern shops, which are of two types—"independent" and "integrated."

Independent pattern shops are separate establishments which make patterns for sale to foundries and to users of castings, such as machinery plants. (These users furnish the patterns, along with their orders for castings, to foundries which do not have their own pattern departments.) The integrated, or "corporation," type of pattern shop is part of an industrial establishment. An integrated shop may be operated in conjunction with a foundry (which uses the patterns). On the other hand, it may be the pattern department of a plant which buys castings from a commercial foundry, supplying the appropriate patterns with each new order for castings.

Since patternmaking need not be performed in a foundry establishment, it is not, in a strict sense, entirely a foundry occupation. In spite of this, patternmaking is so closely associated with foundry work that it is included in the scope of this study.

Patternmakers are classified primarily according to the kind of material they use in making patterns. Those who construct wooden patterns constitute about two-thirds of the total. Of the remainder, most are metal patternmakers, although there are a few who work with other materials, such as plaster.

The Work of the Patternmaker

The patternmaker begins a typical job by studying a blueprint of the desired casting. Working from the blueprint, he plans the pattern, taking into account the manner in which the object will be cast and the type of metal to be used. To do this properly, the patternmaker must understand general foundry practice. After planning the work procedure to be followed, he makes the pattern. At this point the work of wood and metal patternmakers differs.

PHOTO BY U. S. DEPARTMENT OF LABOR

Finishing a pattern.

The wood patternmaker selects the appropriate wood stock and "lays out" the pattern, marking the design for each section on the proper piece of wood. Using power saws, he cuts each piece of wood roughly to width and length. He then shapes the rough pieces into their final form, using various woodworking machines—such as borers, lathes, planers, band saws, and sanders—as well as many small hand tools. Finally, he assembles the pattern segments by hand.

The duties of a metal patternmaker differ from those of a wood patternmaker principally in that metal and metalworking equipment are substituted for wood and woodworking equipment. Metal patternmakers prepare metal patterns from metal stock, or, more commonly, from rough castings made from an original wood pattern. To shape and finish their work, they use a variety of metalworking machines, including the engine lathe, drill press, milling machine, power hacksaw, grinder, and shaper. Apart from these differences, metal patternmaking is similar to work on wood patterns, requiring blueprint reading and lay-out.

Throughout his work the patternmaker carefully checks each dimension of the pattern. A high degree of accuracy is required, since any imperfection in the pattern will be reproduced in the castings made from it. Other duties of patternmakers include making core boxes (in much the same manner as patterns are constructed) and repairing patterns and core boxes.

Qualifications and Training

Apprenticeship, or a similar program of on-the-job training, is the principal means of qualifying as a journeyman patternmaker. Because of the high degree of skill and the wide range of knowledge needed for patternmaking, it is very difficult to obtain the necessary training through informally "picking up" the trade. Good trade school courses in patternmaking provide useful preparation for the prospective apprentice, and may in some cases be credited toward completion of the apprentice period. However, these courses do not substitute for apprenticeship or other on-the-job training.

The usual apprentice period for patternmaking is 5 years, or about 10,000 working hours. In addition, at least 720 hours of class-room instruction in related technical subjects is normally provided during apprenticeship. Since wood and metal patternmaking differ in certain essential respects, there are separate apprenticeships for each type.

The patternmaker apprentice begins by helping journeymen in routine duties. Then he makes simple patterns under close supervision, gradually learning to use the various types of machine and hand tools. As his training progresses, the work becomes increasingly complex and the supervision more general. In order to give the apprentice the necessary background in foundry work, it is common to assign him to a foundry as a helper for a short period.

Employers generally prefer high school graduates as patternmaker-apprentices, and many require this amount of schooling as a minimum. In selecting apprentices, employers often review the applicants' scholastic records, with special attention to grades in mathematics, science, and shop courses.

Patternmaking, although not strenuous, requires considerable standing and moving about; the usual physical standards for apprentices take this into account. A high degree of manual dexterity is especially important because of the precise nature of many hand operations. To all practical purposes, this is entirely a man's occupation.

Employment Outlook

It is expected that more patternmakers will be employed during the next few years than before or during the war. Although the general rate of foundry activity will probably be somewhat below that of 1944—when a total of about 14,000 journeymen patternmakers were employed—other factors will act to increase the number of patternmaker jobs. Because of the likelihood of numerous and rapid changes in the design of many products in the reconverted industries and the consequent need for new patterns for redesigned cast parts, the demand for patterns will probably be proportionately greater than the demand for castings. In addition, the return to a 40-hour workweek in pattern shops, in place of the substantially longer wartime schedules, should more than offset any decrease in requirements for patternmakers resulting from the loss of certain types of wartime business.

The supply of fully qualified patternmakers did not keep pace with expanded wartime needs, because of entry into military service of a number of the younger workers. (Prior to the beginning of large-scale demobilization, there were over 1,500 patternmakers—journeymen and apprentices—in uniform.)

In spite of the favorable employment outlook for patternmakers it is not probable that the demand for these workers will in the next few years substantially exceed the supply, in view of the number of experienced veterans who have returned to their civilian trade. Thus, new openings will be limited largely to replacement needs, which for the next 5-year period should not be more than about 2,000 on the basis of the probable rates of death and retirement. The number of journeymen shifting from patternmaking to other occupations is small, and few jobs for new workers will come from this source. However, because drop-outs in apprenticeship are fairly common, there should be many more apprentice openings than the need for newly trained journeymen indicates.

After several years of high employment, the number of patternmakers jobs will decline slightly, reflecting the general downward trend in foundry activity that will set in after the accumulated demand for civilian durable goods has been met. However, this decrease in patternmaking employment will result primarily in reducing the opportunities for entry into the occupation rather than in leading to the unemployment of experienced men. In the longer run, the employment level should be fairly stable.

Journeymen patternmakers may be advanced to supervisory positions in pattern shops, or may, when patternmaking employment is not available, find jobs in related fields. Wood patternmakers can qualify for nearly every kind of skilled woodworking job—cabinetmaking, for example. Metal patternmakers are suited for many types of machine shop work, including the jobs of machinist, machine-tool operator, and lay-out man.

In conclusion, it is indicated that there are good prospects for stable employment in this highly skilled field, but that opportunities for entry are limited mainly to the relatively small number of openings created by replacement needs.

Earnings

Patternmaking is among the highest-paid occupations in manufacturing. In January 1945, average straight-time earnings of wood patternmakers in independent ferrous foundries (excluding cast-iron pipe foundries) were $1.34 an hour; in independent nonferrous foundries, $1.45; and in pattern shops in the machinery industries (excluding the machine-tool, machine-tool accessories, and electrical machinery industries), $1.23. Wage rates in independent pattern shops tend to be somewhat higher. Straight-time earnings in independent pattern shops in Detroit (one of the highest-wage areas) in April 1944 averaged $2.01 an hour for wood patternmakers and $1.99 an hour for metal patternmakers. The averages for individual shops in this area ranged from $1.90 to $2.50 an hour.

Apprentices to the trade receive between one-fifth and one-third of the journeyman rate in their first 6 months of apprenticeship and are advanced gradually as they progress through the 5-year training period.

Employment Outlook in Other Foundry Occupations

There is a large class of distinctive foundry jobs, apart from those classed as apprenticeable, which are an important source of employment. From among the many occupations in this category, five—chippers and grinders, castings inspectors, foundry technicians, sand mixers, and melters—have been selected on the basis of skill requirements or numerical importance or both, for detailed discussion in this study. Some of the other occupations of a similar nature are noted briefly below.

Pourers transport molten metal from the furnace units to the molding floor and pour the metal into molds. *Molder's helpers* and *coremaker's helpers* work with journeymen and relieve them of certain routine tasks. *Core-oven tenders* operate the furnaces in which cores are baked. *Core assemblers* put together core sections to form completed cores. *Shake-out men* remove castings from the molds in which they were cast. Equipment which mechanically cleans castings is operated by *sandblasters* and *tumbler operators*. *Heat treaters* fire and regulate the annealing furnaces used to improve the properties of many castings.

Chippers and Grinders

Chippers and grinders constitute a large group of workers, most of them semiskilled, in the cleaning and finishing departments of foundries. Chipping consists of removing the excess metal from castings by means of pneumatic hammers or hand hammers and chisels. In grinding, a mechanically powered abrasive wheel is used to smooth and finish castings. Although chipping and grinding may be separate occupations, they are often combined into one job, especially in the smaller foundries. There are variations in skill requirements, depending on the intricacy of the castings on which work is done, the degree of precision required, and the amount of supervision given the worker.

The basic duties of the chipper or grinder are generally learned in a brief period of on-the-job training, and there is no special form of preparation needed. Persons without previous foundry experience may be hired directly, or foundry laborers may be upgraded to this

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Grinding a Casting.

work. Considerable experience in chipping and grinding is required, however, to qualify for the more intricate, precise, and responsible duties.

In many respects, chipping and grinding involves quite strenuous work and at least average strength is needed. Consequently, relatively few women are employed in this occupation, and these only for work on small castings. Chippers and grinders may be promoted to more skilled or responsible jobs, such as inspector or foreman, in the finishing departments of foundries.

Employment prospects for chippers and grinders are favorable for the next 2- or 3-year period, particularly in areas in which gray-iron and malleable-iron foundries predominate. Although employment in this occupation will be below the wartime peak in foundries as a whole, transfers to other lines of work have tended to balance supply and demand. Since chippers and grinders, taken together, constitute one of the largest of the foundry occupations—about 50,000 were employed in 1944—there will be many openings for new workers resulting from withdrawals.

The longer-run outlook is slightly less favorable. The growing use of molding methods—such as permanent mold casting—which reduce the amount of finishing required will result in some decline in the employment of chippers and grinders. However, this will be a gradual development, and the more-skilled workers in the occupation will probably not be displaced.

In January 1945, straight-time hourly earnings of male chippers and grinders averaged $1.06 in independent ferrous foundries (excluding cast-iron pipe foundries); 95 cents in independent nonferrous foundries; and 91 cents in the captive foundries of the machinery industries (excluding the electrical equipment, machine-tool and machine-tool accessories industries).

Castings Inspectors

These are workers in the cleaning and finishing departments of foundries who look over finished castings to see if there are structural defects, such as cracks or blowholes, and check the measurements against the tolerances shown on blueprints. The more skilled inspectors are able to read blueprints, to work on widely different types of castings, and to mark partially defective castings to show what should be done to salvage them. The less-skilled do routine measuring and checking of large numbers of identical castings under close supervision.

Skilled inspectors' jobs are usually filled by promotion from lower-grade inspection jobs or other cleaning and finishing occupations, such as that of chipper and grinder. For the less-skilled work, previous foundry experience may not be needed. Physical requirements depend on the size of castings inspected and the availability of mechanical handling equipment. In the lighter types of inspection work, a small number of women are employed, mainly for the less-skilled jobs. Skilled inspectors may be promoted to the jobs of chief inspector and cleaning-room foreman.

During the next few years, the total number of inspectors employed will fall short of the peak wartime level. (About 15,000 were employed in 1944.) However, a fairly strong demand for skilled inspectors is anticipated and, since the supply of these workers was not greatly increased during the war, there should be ample employment opportunities for experienced men as well as some openings for those qualified to learn the work. The number of persons with experience in routine inspection will probably exceed the demand for this type of worker, but a high rate of transfer into other occupations should create some openings for new entrants. The longer-run outlook for both skill classes is for a fairly stable level of employment.

Male class A inspectors in January 1945 earned an average of $1.06 per hour (straight time) in independent ferrous foundries (excluding cast-iron pipe foundries); $1.19 in independent nonferrous foundries. Male inspectors of the lower-skill grades averaged from 5 to 25 cents per hour less. Earnings of women in this occupation were in most cases markedly lower than those of men at comparable skill grades.

Foundry Technicians

This is a group of skilled occupations having to do with quality control in the making of castings. Included are workers with such specialized duties as testing of molding and coremaking sands, chemical analysis of metal, operation of machines which test the strength and hardness of castings, and use of X-ray or magnetic apparatus to inspect the internal structure of castings.

In general, a high school education is prerequisite, and employers may require additional technical schooling. However, most of the foundry technician's duties are learned on the job. Physical strength is not ordinarily needed, and women are often employed. Foundry technicians may advance to supervisory positions in their various specialized fields.

The employment of foundry technicians during the next few years will closely approach the peak war level and, in areas in which gray-iron and malleable-iron foundries are particularly important, may well exceed the wartime high. Morever, there should be a gradual expansion of employment opportunities, resulting from the long-run trend toward greater use of scientific methods in casting metal. However, although this is a growing occupation, it is numerically small, and, consequently, only a limited number of openings are likely in any one year.

Sand Mixers

Sand mixers prepare sand for use in molding and coremaking. They cleanse the sand of scrap, moisten the sand with water as required, add the necessary binding ingredients in the proper proportions, and mix the sand by means of hand shovels or mechanical sand-mixing machines. They may test samples of the mixed sand to determine its quality and consistency.

The work is usually learned in a brief period of on-the-job training. Inexperienced persons may be hired as trainees, or laborers may be upgraded to fill vacancies. There are no special educational qualifications. At least average strength is needed for hand work; machine sand mixing is less strenous. Only a very few women are employed as sand mixers. Qualified workers in this occupation may be promoted to supervisory positions in sand-preparation departments.

The number of jobs for hand and machine sand mixers during the next few years will be below the wartime level. (In 1944, approximately 10,000 sand mixers were employed.) However, if allowance is made for withdrawals from this occupation there should be some openings for new workers, especially in gray-iron and malleable-iron foundries. In the longer-run period, increased use of mechanical mixing methods will reduce the need for hand mixers, but those experienced in the use of sand-mixing machines should continue to find employment.

Average straight-time hourly earnings of male sand mixers in January 1945 were as follows: Independent ferrous foundries (excluding cast-iron pipe foundries), 87 cents; independent nonferrous foundries, 85 cents; captive foundries in the machinery industries (excluding the electrical machinery, machine-tool, and machine-tool accessories industries), 80 cents.

Melters

A foundry melter operates or directs the operation of a furnace unit used to melt metal for castings. In general, the work involves charging the furnace with the necessary materials—such as metal ingot and scrap, controlling the furnace temperature, pouring off the molten metal, and, in some cases, maintaining the furnace in good operating condition. The melter may supervise a small group of helpers and laborers or he may operate one of the smaller types of melting units without assistance. A melter usually specializes on a particular type of furnace—cupola, open-hearth, air, electric, crucible, or reverberatory. Skill requirements vary considerably, depending on the amount of supervision given the melter and on the particular kind of furnace used.

As a rule, there are no apprenticeships or other organized training programs provided for melters. The less-skilled melting jobs are learned in a brief period of informal training. The usual way to get one of the more-skilled jobs is to begin as a furnace helper and gradually to pick up the skills of the melter's work. When a vacancy for the position of melter occurs, an experienced and competent helper is eligible. The more-skilled melters must have some familiarity with general foundry practice, shop arithmetic, and certain practical aspects of chemistry and metallurgy. Since the duties of helpers are in many respects strenuous, physical requirements are fairly high and normally only men are employed.

Employment prospects for the next few years are favorable for skilled melters—a small group which has shown little increase during the wartime expansion of foundry employment generally. Although no statistical data on the age of these workers are available it is believed that replacement demand will operate at a relatively high rate during the next 5 or 10 years. Thus, there should be opportunities for a limited number of workers to train as replacements. The number of jobs at the less-skilled level will be below the wartime peak, but since many of these men have left foundry work there should be some openings for newcomers.

The long-run trend is for a fairly steady volume of employment in this occupation. There is, however, a definite tendency to simplify the work of the more-skilled melters by transferring some of their responsibilities to technical employees.

Working Conditions in Foundries

The working environment varies greatly among individual foundries. Some compare favorably with metalworking operations as a whole in such respects as frequency and severity of accidents, incidence of industrial disease, and plant cleanliness, ventilation, and temperature. Others fall far below the metalworking average in safety and comfort. Because of this wide range, generalizations on foundry working conditions are likely to be somewhat misleading. However, with this limitation in view, the following information may be helpful to those considering going into foundry work.

Hazards [1]

The accident frequency and severity rates for independent ferrous foundries, as shown below, greatly exceed the averages for the group of industries producing iron and steel and iron and steel products other than machinery.[2]

	Independent ferrous foundries		*Iron and steel industry group*	
	Frequency rate	*Severity rate*	*Frequency rate*	*Severity rate*
1939	35.9	2.8	17.6	2.0
1940	36.1	2.2	17.9	2.0
1941	47.0	3.2	22.5	2.1
1942	49.7	2.9	24.7	2.0
1943	43.4	3.2	24.1	2.0
1944	43.0	2.3	24.3	1.8
1945	41.8	2.6	21.6	1.8

It should be noted that the sharp wartime increase shown by the ferrous foundry frequency and severity rates reflects mainly more intensive operations, as well as the influx of inexperienced workers, rather than any deterioration of safety precautions. A significant improvement between 1942 and 1945 in the accident record of the industry is also apparent. Moreover, in one important respect, independent ferrous foundries compare favorably with the iron and steel group: in the peak accident year of 1942, only 0.4 percent of the injuries occurring in the ferrous foundries resulted in death or permanent total disability; for the iron and steel industry group this rate was 0.8 percent.

Data available for 2,188 foundries, including both captive and independent types, show the 1942 accident records for each of the major classes:

	Frequency rate	*Severity rate*
Ferrous job foundries	52.0	3.1
Gray-iron	55.8	3.4
Malleable-iron	49.3	2.5
Steel	50.8	2.9
Cast-iron pipe	46.2	3.8
Nonferrous job foundries	35.3	1.6
Foundries other than job foundries	37.3	3.2

A more favorable aspect of foundry safety is indicated by the fact that no disabling injuries occurred during 1942 in 63 percent of the nonferrous job foundries, 24 percent of the ferrous job foundries, and 29 percent of the nonjob foundries. The frequency rates were below the 1942 average for all manufacturing industry in an addi-

[1] Industrial hazards data used in this section are drawn primarily from published studies of the Bureau's Industrial Hazards Division. For a detailed analysis of safety in foundries, see Bull. No. 805: Injuries and Accident Causes in the Foundry Industry, 1942.
[2] The frequency rate refers to the average number of disabling injuries for each million employee-hours worked. The severity rate is the average number of days lost per thousand employee-hours worked.

tional 6 percent of the nonferrous job foundries, 10 percent of ferrous job foundries, and 14 percent of the nonjob foundries.

Hand movement of heavy materials is a major source of foundry accidents, resulting in sprains and in crushed fingers or toes. Objects dropped from overhead cranes are responsible for some of the more serious accidents. Spilled or splashed molten metal may endanger many workers on the foundry floor. Falls may result from tripping over tools, scrap metal, or other objects left lying about. Marked differences in temperature among the various parts of a foundry tend to increase the workers' susceptibility to colds and other respiratory ailments.

Foundry workers may be exposed to the danger of silicosis, an industrial disease, in which, because silica dust is inhaled, normal lung tissue is damaged, weakening the respiratory system and in some cases leading to tuberculosis and pneumonia. However, the incidence of silicosis is actually quite low and it is a relatively minor source of disability. (In 65 ferrous foundries surveyed, industrial disease, including silicosis, accounted for substantially less than 1 percent of all disabling injuries occurring in 1942.)

The frequency of accidents tends to vary greatly among the various major departments of foundries. In general, pattern shops and core rooms are the least hazardous; molding departments are somewhat more hazardous; and shake-out, melting, and cleaning and finishing operations show the highest injury rates.

Hazards associated with foundry work are in large measure preventable by such means as good "housekeeping" (the orderly arrangement of materials and tools), providing special safety equipment for, certain operations, furnishing machinery for heavy lifting, and training workers in safe practices. The danger of silicosis may be largely eliminated by the installation of dust-control equipment. In recent years, substantial progress has been made in these respects, especially in dust control.

Other Conditions of Work

Smoke and fumes are often a nuisance in foundries, although where adequate ventilating systems have been installed discomfort from these sources has been minimized. Heat may be excessive near the melting units, especially in warm weather, and inadequate in other parts of the establishment during the winter. However, better regulation of temperature has been achieved in many foundries. Noise may be a problem in certain operations, particularly in cleaning and finishing. Personal cleanliness in foundry work is difficult because of the extensive use of sand in the casting process. However, good housekeeping has in many cases kept this problem under control. In addition, a large number of foundries now provide showers for their employees.

The large majority of foundry workers are union members; the principal labor organizations covering foundry workers include the International Molders and Foundry Workers Union of North America (AFL), the United Steelworkers of America (CIO), and the United Automobile, Aircraft and Agricultural Implement Workers of America (CIO). Most patternmakers belong to the Pattern Makers' League of North America (AFL).

The scheduled workweek in foundries, prior to the war, was typically about 40 hours. During the war, hours in most foundries were lengthened to a schedule of 48 or more per week. It is probable that a 40-hour week will again be customary in the postwar years.

In peacetime, there is some seasonal unemployment of foundry workers. The degree of seasonal change in employment differs among foundries, depending mainly on the industry or industries providing the principal market for the castings output of a given establishment. For example, the amount of seasonal variation in foundries making automotive castings is influenced in large part by the seasonality of automobile production. In general, foundry work is comparable to most other metalworking in regularity of employment.

Appendix

Average Straight-Time Hourly Earnings [1] for Selected Occupations in Independent Foundries, by Wage Area, January 1945 [2]

Type of foundry, occupation, and grade	United States	Baltimore	Boston	Buffalo	Chicago	Cincinnati	Cleveland
Ferrous foundries							
Chippers and grinders	$1.06	$1.23	$0.82	$1.06	$1.14	$0.85	$1.14
Coremakers, hand	1.22	1.02	1.14	1.20	1.35	1.20	1.50
Coremakers, turn-over draw machine	1.26	1.36	(3)	1.29	-------	(3)	1.45
Inspectors, class B	1.01	-------	-------	1.01	.97	(3)	.99
Inspectors, class C	.88	.85	-------	.85	.97	.73	.89
Molders, hand, bench	1.14	(3)	1.12	1.20	1.24	1.20	1.30
Molders, floor	1.17	1.17	1.12	1.25	1.24	1.21	1.38
Molders, machine	1.31	1.45	1.13	1.38	1.42	1.34	1.48
Patternmakers, wood	1.34	1.18	1.11	1.31	1.47	1.25	1.60
Sand mixers, hand and machine	.87	.74	.78	.90	.88	.79	1.09
Nonferrous foundries							
Chippers and grinders	.95	.79	.89	.99	.84	.86	1.15
Coremakers, hand	1.24	1.04	1.15	1.19	1.29	1.20	1.45
Coremakers, turn-over draw machine	1.29	-------	-------	-------	1.62	(3)	-------
Inspectors, class B	1.10	(3)	(3)	(3)	.93	.73	1.12
Inspectors, class C	.94	.87	-------	1.06	.93	.64	.99
Molders, hand, bench	1.22	1.02	1.16	1.18	1.20	1.22	1.27
Molders, floor	1.35	1.21	1.16	1.44	1.24	(3)	1.58
Molders, machine	1.29	.95	1.24	1.24	1.48	1.40	1.37
Patternmakers, wood	1.45	1.34	(3)	(3)	1.67	1.33	1.46
Sand mixers, hand and machine	.85	.79	.80	.99	.83	.76	.87

Type of foundry, occupation, and grade	Detroit	Indianapolis	Los Angeles	Milwaukee	Newark	Philadelphia	Pittsburgh	San Francisco
Ferrous foundries								
Chippers and grinders	$1.36	$1.12	$0.94	$1.15	$0.82	$1.07	$0.97	$1.08
Coremakers, hand	1.43	1.12	1.26	1.28	1.20	1.43	1.13	1.28
Coremakers, turn-over draw machine	-------	(3)	-------	1.36	1.14	(3)	1.27	(3)
Inspectors, class B	1.11	(3)	.94	.96	.92	1.09	1.03	(3)
Inspectors, class C	.98	1.36	.93	.88	(3)	.97	.88	-------
Molders, hand, bench	1.35	1.12	1.28	1.31	1.19	1.26	1.15	1.30
Molders, floor	1.47	1.20	1.30	1.29	1.22	1.27	1.12	1.29
Molders, machine	1.57	1.21	1.51	1.43	1.31	1.30	1.22	1.29
Patternmakers, wood	1.42	1.52	1.50	1.09	1.19	1.39	1.35	1.59
Sand mixers, hand and machine	1.06	.97	.95	.90	.76	.81	.83	.95
Nonferrous foundries								
Chippers and grinders	1.23	.82	1.01	1.07	.85	.88	.92	1.09
Coremakers, hand	1.42	1.13	1.25	1.37	1.26	1.20	1.18	1.33
Coremakers, turn-over draw machine	1.41	(3)	1.22	(3)	1.08	1.23	.91	1.38
Inspectors, class B	1.47	-------	1.05	(3)	(3)	(3)	.93	-------
Inspectors, class C	1.29	.76	.94	1.08	-------	.80	.72	(3)
Molders, hand, bench	1.37	1.19	1.33	1.15	1.22	1.27	1.23	1.35
Molders, floor	1.37	1.33	1.33	1.46	1.29	1.39	1.37	1.37
Molders, machine	1.25	1.13	1.34	1.47	1.13	1.20	1.26	1.36
Patternmakers, wood	-------	1.69	1.60	1.24	(3)	-------	1.30	(3)
Sand mixers, hand and machine	1.26	.74	.95	.91	.81	.78	.72	.98

[1] Excluding premium pay for overtime and night work. Averages are for male workers only.
[2] Data are from the Bureau's Wage Analysis Branch. Further information on wages as well as on wage and related practices in independent foundries is obtainable from the Wage Analysis Branch. Local summaries are available for selected cities of 100,000 or more; regional and national summaries are provided in 2 mimeographed reports, (1) Wage Structure: Foundries, 1945, and (2) Occupational Wage Relationship: Foundries, 1945.
[3] Insufficient number of workers to justify comparison.

Occupational Outlook Publications of the Bureau of Labor Statistics

This bulletin is one of a series of reports on employment trends and opportunities in the various occupations and professions, for use in the vocational guidance of veterans, young people in schools, and others considering the choice of an occupation. The reports describe the long-run outlook for employment in each occupation and give information on earnings, working conditions, and the training required.

Reports are usually first published in the Monthly Labor Review (subscription price per year, $3.50) and are reprinted as bulletins. Both the Monthly Labor Review and the bulletins may be purchased from the Superintendent of Documents, Washington 25, D. C. Following is a list of other bulletins in the series, with their prices and with the dates of the publication of articles in the Monthly Labor Review:

Employment Opportunites for Diesel-Engine Mechanics.
Bulletin No. 813 (1945), price 5 cents. (Monthly Labor Review, February 1945.)

Occupational Data for Counselors, A Handbook of Census Information Selected for Use in Guidance.
Bulletin No. 817 (1945), price 10 cents. (Prepared jointly with the U. S. Office of Education.)

Postwar Employment Prospects for Women in the Hosiery Industry.
Bulletin No. 835 (1945), price 5 cents. (Monthly Labor Review, May 1945.)

Employment Opportunities in Aviation Occupations, Part I—Postwar Employment Outlook.
Bulletin No. 837–1 (1945), price 10 cents. (Monthly Labor Review, April and June 1945.)

Employment Opportunities in Aviation Occupations, Part II—Duties, Qualifications, Earnings, and Working Conditions.
Bulletin No. 837–2 (1946), [in press]. (Monthly Labor Review, August 1946.)

Employment Outlook for Automobile Mechanics.
Bulletin No. 842 (1945), price 10 cents.

Employment Opportunities for Welders.
Bulletin No. 844 (1945), price 10 cents. (Monthly Labor Review, September 1945.)

Postwar Outlook for Physicians.
Bulletin No. 863 (1946), price 10 cents. (Monthly Labor Review, December 1945.)

Factors Affecting Earnings in Chemistry and Chemical Engineering.
Bulletin No. 881 (1946), price 10 cents. (Monthly Labor Review, June 1946.)