Qualifications for computer-control programmers vary widely depending upon the complexity of the job. Employers often prefer skilled machinists or those with technical school training. For some specialized types of programming, such as that needed to produce complex parts for the aerospace or shipbuilding industries, employers may prefer individuals with a degree in engineering.

For those entering CNC programming directly, a basic knowledge of computers and electronics is necessary, and experience with machine tools is extremely helpful. Classroom training includes an introduction to computer numerical control, the basics of programming, and more complex topics, such as computer-aided manufacturing. Trainees start writing simple programs under the direction of an experienced programmer. Although machinery manufacturers are trying to standardize programming languages, there are numerous languages in use. Because of this, computer-control programmers and operators should be able to learn new programming languages.

As new automation is introduced, computer-control programmers and operators normally receive additional training to update their skills. This training usually is provided by a representative of the equipment manufacturer or a local technical school. Many employers offer tuition reimbursement for job-related courses.

Computer-control programmers and operators can advance in several ways. Experienced CNC operators may become CNC programmers, and some are promoted to supervisory or administrative positions in their firms. A few open their own shops.

Job Outlook

Computer-control programmers and operators should have excellent job opportunities. Due to the limited number of people entering training programs, employers are expected to continue to have difficulty finding workers with the necessary skills and knowledge. Employment of computer-control programmers and operators is projected to grow about as fast as the average for all occupations through 2010. Job growth will be driven by the increasing use of CNC machine tools, but advances in CNC machine tool technology will further simplify minor adjustments, enabling machinists and tool and die makers to perform tasks that previously required computer-control operators. In addition, the demand for computer-control programmers will be negatively affected by the increasing use of software that automatically translates part and product designs into CNC machine tool instructions.

Employment levels of computer-control programmers and operators are influenced by economic cycles—as the demand for machined goods falls, programmers and operators involved in production may be laid off or forced to work fewer hours.

Earnings

Median hourly earnings of computer-controlled machine tool operators, metal and plastic, were about $13.17 in 2000. The middle 50 percent earned between $10.48 and $16.55. The lowest 10 percent earned less than $8.80, whereas the top 10 percent earned more than $20.25. Median hourly earnings in the manufacturing industries employing the largest number of computer-controlled machine tool operators, metal and plastic, in 2000 were:

Metalworking machinery	$15.20
General industrial machinery	15.06
Industrial machinery, not elsewhere classified	13.05
Motor vehicles and equipment	12.05
Miscellaneous plastics products, not elsewhere classified	11.35

Median hourly earnings of numerical tool and process control programmers were $17.70 in 2000. The middle 50 percent earned between $13.81 and $21.74. The lowest 10 percent earned less than $10.39, while the top 10 percent earned more than $26.66.

Related Occupations

Occupations most closely related to computer-control programmers and operators are other metal worker occupations. These include machinists; tool and die makers; machine setters, operators, and tenders—metal and plastic; and welding, soldering, and brazing workers.

Numerical tool and process control programmers apply their knowledge of machining operations, metals, blueprints, and machine programming to write programs that run machine tools. Computer programmers also write detailed programs to meet precise specifications.

Sources of Additional Information

For general information about computer-control programmers and operators, contact:

➤ Precision Machine Products Association, 6700 West Snowville Rd., Brecksville, OH 44141-3292. Internet: **http://www.pmpa.org**

For a list of training centers and apprenticeship programs, contact:

➤ National Tooling and Metalworking Association, 9300 Livingston Rd., Fort Washington, MD 20744. Internet: **http://www.ntma.org**

For general occupational information, including a list of training programs, contact:

➤ PMA Educational Foundation, 6363 Oak Tree Blvd., Independence, OH 44131-2500. Internet: **http://www.pmaef.org**

Machinists

(O*NET 51-4041.00)

Significant Points

- Machinists learn in apprenticeship programs, informally on the job, and in high schools, vocational schools, or community or technical colleges.
- Many entrants previously have worked as machine setters, operators, or tenders.
- Job opportunities are expected to be excellent.

Nature of the Work

Machinists use machine tools, such as lathes, milling machines, and spindles, to produce precision metal parts. Although they may produce large quantities of one part, precision machinists often produce small batches or one-of-a-kind items. They use their knowledge of the working properties of metals and their skill with machine tools to plan and carry out the operations needed to make machined products that meet precise specifications.

Before they machine a part, machinists must carefully plan and prepare the operation. These workers first review blueprints or written specifications for a job. Next, they calculate where to cut or bore into the workpiece (the piece of metal that is being shaped), how fast to feed the metal into the machine, and how much metal to remove. They then select tools and materials for the job, plan the sequence of cutting and finishing operations, and mark the metal stock to show where cuts should be made.

After this layout work is completed, machinists perform the necessary machining operations. They position the metal stock on the machine tool—spindle, drill press, lathe, milling machine, or other—set the controls, and make the cuts. During the machining process,

Machinists cut and shape metal products using machine tools.

they must constantly monitor the feed and speed of the machine. Machinists also ensure that the workpiece is being properly lubricated and cooled, because the machining of metal products generates a significant amount of heat. The temperature of the workpiece is a key concern because most metals expand when heated; machinists must adjust the size of their cuts relative to the temperature. Some rarer, but increasingly popular, metals, such as titanium, are machined at extremely high temperatures. Machinists also adjust cutting speeds to compensate for harmonic vibrations, which can decrease the accuracy of cuts, particularly on newer high-speed spindles and lathes.

Some machinists, often called production machinists, may produce large quantities of one part, especially parts requiring the use of complex operations and great precision. Production machinists work with complex computer numerically controlled (CNC) cutting machines. Frequently, machinists work with computer-control programmers to determine how the automated equipment will cut a part. (See the statement on computer-control programmers and operators elsewhere in the *Handbook*.) The programmer determines the path of the cut, and the machinist determines the type of cutting tool, the speed of the cutting tool, and the feed rate. After the production process is designed, relatively simple and repetitive operations normally are performed by machine setters, operators, and tenders. (See the statement on machine setters, operators, and tenders—metal and plastic elsewhere in the *Handbook*.) Other machinists do maintenance work—repairing or making new parts for existing machinery. To repair a broken part, maintenance machinists may refer to blueprints and perform the same machining operations that were needed to create the original part.

Working Conditions

Most machine shops of today are relatively clean, well lit, and ventilated. Many computer-controlled machines are totally enclosed, minimizing the exposure of workers to noise, dust, and the lubricants used to cool workpieces during machining. Nevertheless, working around machine tools presents certain dangers, and workers must follow safety precautions. Machinists wear protective equipment such as safety glasses to shield against bits of flying metal and earplugs to dampen machinery noise. They also must exercise caution when handling hazardous coolants and lubricants. The job requires stamina, because machinists stand most of the day and, at times, may need to lift moderately heavy workpieces.

Most machinists work a 40-hour week. Evening and weekend shifts are becoming more common as companies justify investments in more expensive machinery by extending hours of operation. Overtime is common during peak production periods.

Employment

Machinists held about 430,000 jobs in 2000. Most machinists work in small machining shops or in manufacturing firms that produce durable goods, such as metalworking and industrial machinery, aircraft, or motor vehicles. Maintenance machinists work in most industries that use production machinery. Although machinists work in all parts of the country, jobs are most plentiful in the Northeast, Midwest, and West, where manufacturing is concentrated.

Training, Other Qualifications, and Advancement

Machinists train in apprenticeship programs, informally on the job, and in high schools, vocational schools, or community or technical colleges. Experience with machine tools is helpful. In fact, many entrants previously have worked as machine setters, operators, or tenders. Persons interested in becoming machinists should be mechanically inclined, able to work independently, and able to do highly accurate work that requires concentration and physical effort.

High school or vocational school courses in mathematics, blueprint reading, metalworking, and drafting are highly recommended. Apprenticeship programs consist of shop training and related classroom instruction. In shop training, apprentices work almost full time, and are supervised by an experienced machinist while learning to operate various machine tools. Classroom instruction includes math, physics, blueprint reading, mechanical drawing, and quality and safety practices. In addition, as machine shops have increased their use of computer-controlled equipment, training in the operation and programming of CNC machine tools has become essential. Apprenticeship classes are taught in cooperation with local community or vocational colleges. A growing number of machinists learn the trade through 2-year associate degree programs at community or technical colleges. Graduates of these programs still need significant on-the-job experience before they are fully qualified.

To boost the skill level of machinists and to create a more uniform standard of competency, a number of training facilities and colleges have recently begun implementing curriculums incorporating national skills standards developed by the National Institute of Metalworking Skills (NIMS). After completing such a curriculum and passing a performance requirement and written exam, a NIMS credential is granted to trainees, providing formal recognition of competency in a metalworking field. Completing a recognized certification program provides a machinist with better career opportunities.

As new automation is introduced, machinists normally receive additional training to update their skills. This training usually is provided by a representative of the equipment manufacturer or a local technical school. Some employers offer tuition reimbursement for job-related courses.

Machinists can advance in several ways. Experienced machinists may become computer-control programmers and operators, and some are promoted to supervisory or administrative positions in their firms. A few open their own shops.

Job Outlook

Despite projected slower-than-average employment growth, job opportunities for machinists should continue to be excellent. Many

young people with the necessary educational and personal qualifications needed to obtain machining skills may prefer to attend college or may not wish to enter production-related occupations. Therefore, the number of workers obtaining the skills and knowledge necessary to fill machinist jobs is expected to be less than the number of job openings arising each year from employment growth and from the need to replace experienced machinists who transfer to other occupations or retire.

Employment of machinists is expected to grow more slowly than the average for all occupations over the 2000-10 period because of rising productivity among machinists. Productivity gains are resulting from the expanded use of computer-controlled machine tools and new technologies, such as high-speed machining, which reduce the time required for machining operations. This allows fewer machinists to accomplish the same amount of work previously performed by more workers. Technology is not expected to affect the employment of machinists as significantly as that of most other production occupations, however, because many of the unique operations performed by machinists cannot be efficiently automated. Due to modern production techniques, employers prefer workers, such as machinists, who have a wide range of skills and are capable of performing almost any task in a machine shop. In addition, firms are likely to retain their most skilled workers to operate and maintain expensive new machinery.

Employment levels in this occupation are influenced by economic cycles—as the demand for machined goods falls, machinists involved in production may be laid off or forced to work fewer hours. Employment of machinists involved in plant maintenance, however, often is more stable because proper maintenance and repair of costly equipment remain vital concerns, even when production levels fall.

Earnings

Median hourly earnings of machinists were $14.78 in 2000. The middle 50 percent earned between $11.43 and $18.39. The lowest 10 percent earned less than $9.01, while the top 10 percent earned more than $21.84. Median hourly earnings in the manufacturing industries employing the largest number of machinists in 2000 were:

Aircraft and parts	$16.86
Metalworking machinery	15.89
Industrial machinery, not elsewhere classified	14.66
Motor vehicles and equipment	14.24
Personnel supply services	8.80

Related Occupations

Occupations most closely related to that of machinist are other machining occupations. These include tool and die makers; machine setters, operators, and tenders—metal and plastic; and computer-control programmers and operators. Another occupation that requires precision and skill in working with metal is welding, soldering, and brazing workers.

Sources of Additional Information

For general information about machinists, contact:

➤ Precision Machine Products Association, 6700 West Snowville Rd., Brecksville, OH 44141-3292. Internet: **http://www.pmpa.org**

For a list of training centers and apprenticeship programs, contact:

➤ National Tooling and Metalworking Association, 9300 Livingston Rd., Fort Washington, MD 20744. Internet: **http://www.ntma.org**

For general occupational information and a list of training programs, contact:

➤ PMA Educational Foundation, 6363 Oak Tree Blvd., Independence, OH 44131-2500. Internet: **http://www.pmaef.org**

Machine Setters, Operators, and Tenders—Metal and Plastic

(O*NET 51-4021.00, 51-4022.00, 51-4023.00, 51-4031.01, 51-4031.02, 51-4031.03, 51-4031.04, 51-4032.00, 51-4033.01, 51-4033.02, 51-4034.00, 51-4035.00, 51-4051.00, 51-4052.00, 51-4061.00, 51-4062.00, 51-4071.00, 51-4072.01, 51-4072.02, 51-4072.03, 51-4072.04, 51-4072.05, 51-4081.01, 51-4081.02, 51-4191.01, 51-4191.02, 51-4191.03, 51-4192.00, 51-4193.01, 51-4193.02, 51-4193.03, 51-4193.04, 51-4194.00, 51-4199.99)

Significant Points

- A few weeks of on-the-job training is sufficient for most workers to learn basic machine operations, but several years are required to become a skilled operator.
- Employment of most operators is expected to decline, while employment of multiple machine tool operators is projected to grow.

Nature of the Work

Consider the parts of a toaster, such as the metal or plastic housing or the lever that lowers the toast. These parts, and many other metal and plastic products, are produced by metalworking and plastics-working machine operators. In fact, machine tool operators in the metalworking and plastics industries play a major part in producing most of the consumer products on which we rely daily.

In general, these workers can be separated into two groups—those who set up machines for operation and those who tend the machines during production. Setup workers prepare the machines prior to production and may adjust the machinery during operation. Operators and tenders, on the other hand, primarily monitor the machinery during operation, sometimes loading or unloading the machine or making minor adjustments to the controls. Many workers both set up and operate equipment. Because the setup process requires an understanding of the entire production process, setters usually have more training and are more highly skilled than those who simply operate or tend machinery. As new automation simplifies the setup process, however, less skilled workers also are increasingly able to set up machines for operation.

Setters, operators, tenders, and setup operators usually are identified by the type of machine with which they work. Some examples of specific titles are drilling and boring machine toolsetters, milling and planing machine tenders, and lathe and turning-machine tool operators. Job duties usually vary based on the size of the firm and on the type of machine being operated. Although some workers specialize in one or two types of machinery, many are trained to set up or operate a variety of machines. Newer production techniques require machine operators to rotate between, and be proficient with, different machines. The rotating of assignments allows workers more varied work, but also requires them to have a wider range of skills.

Metalworking-machine setters and operators set up and tend machines that cut and form all types of metal parts. Traditionally, setup workers plan and set up the sequence of operations according to blueprints, layouts, or other instructions. They adjust speed, feed, and other controls; choose the proper coolants and lubricants; and select the instruments or tools for each operation. Using micrometers, gauges, and other precision measuring instruments, they also may compare the completed work with the tolerance limits stated in the specifications.