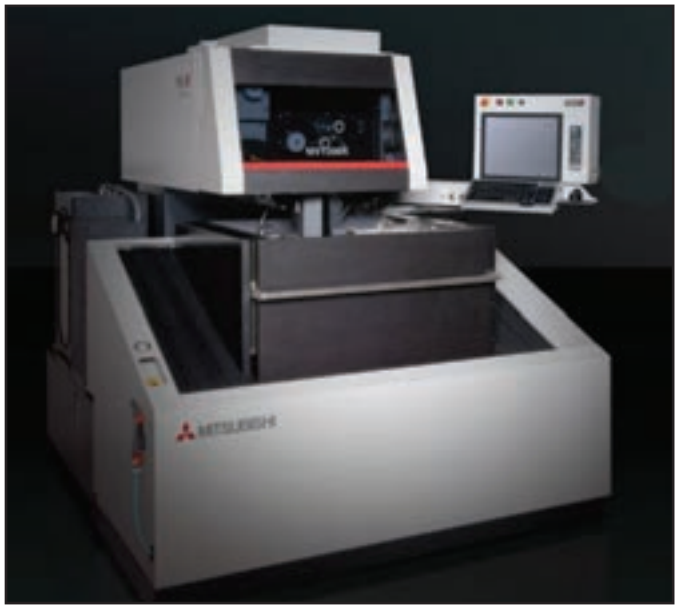
2 Wire EDM Fundamentals

Revolutionizing Machining

Wire Electrical Discharge Machining (EDM) is one of the greatest innovations affecting the tooling and machining industry. This process has brought dramatic improvements to industry in accuracy, quality, productivity, and earnings. Figure 2:1 shows various wire EDM machines.

Courtesy Makino

Courtesy Agie Charmille



Courtesy Mitsubishi

Figure 2:1

Wire Electrical Discharge Machines

Before wire EDM, costly processes were often used to produce finished parts. Now, with the aid of a computer and wire EDM machines, extremely complicated shapes can be cut automatically, precisely, and economically, even in materials as hard as carbide. See Figure 2:2.

Wire EDM Beginnings

In 1969, the Swiss firm Agie produced the world's first wire EDM machine. Typically, these first machines in the early '70s were extremely slow, cutting about 2 square inches an hour (21 mm^2/min.). Their speeds went up in the early '80s to 6 square inches an hour (64 mm^2/min.). Today, machines are equipped with automatic wire threading and can cut over 20 times faster than the beginning machines. A remarkable turnaround.

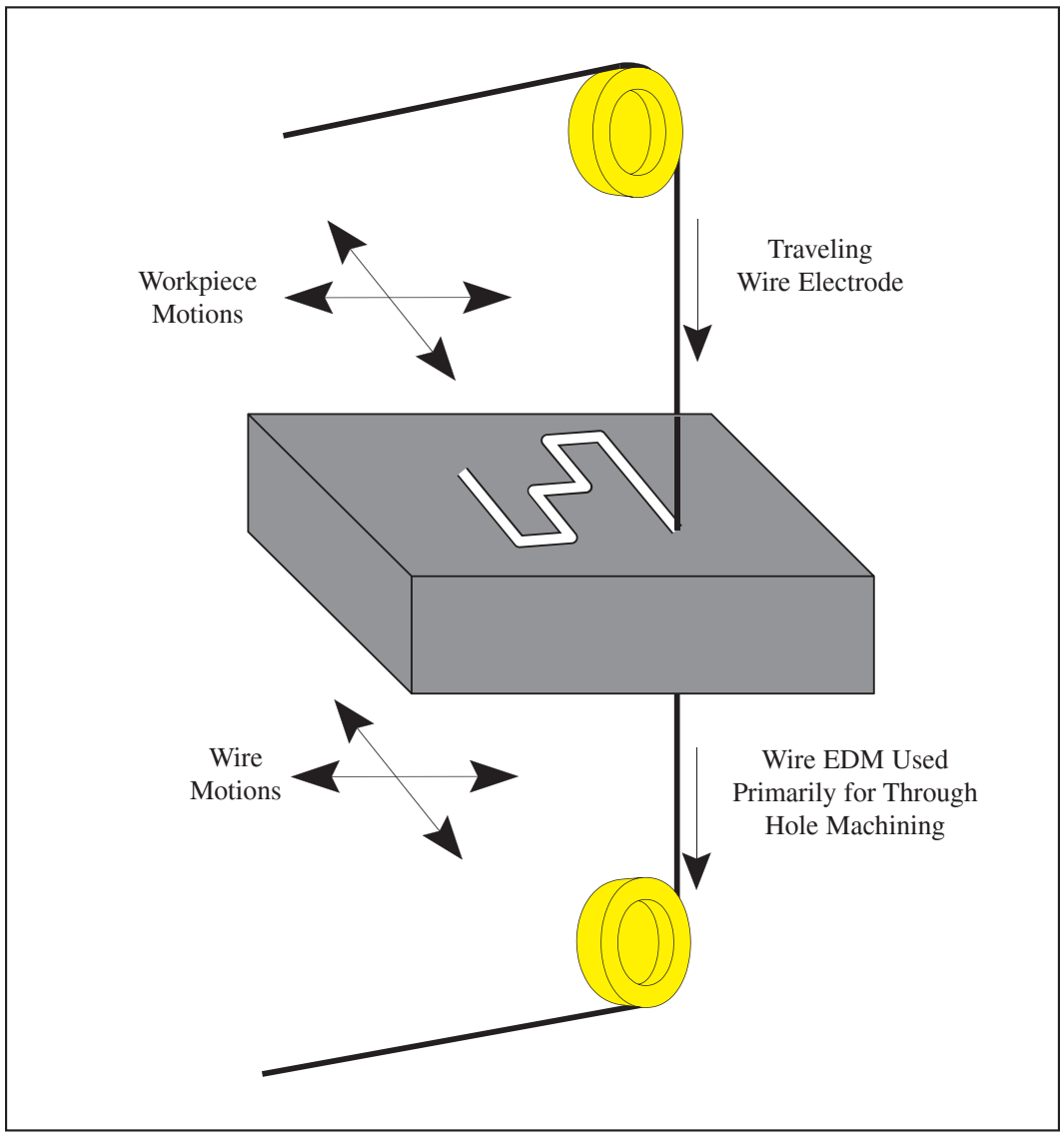


Figure 2:2

Wire Electrical Discharge Machining

Production Wire EDM

Whether cutting soft aluminum, hot rolled steel, super alloys, or tungsten carbide, manufacturers are discovering it is less expensive and they receive higher quality with today's high-speed wire EDM machines for many production parts. See Figure 2:3.

Wire EDMing Internal Keyways

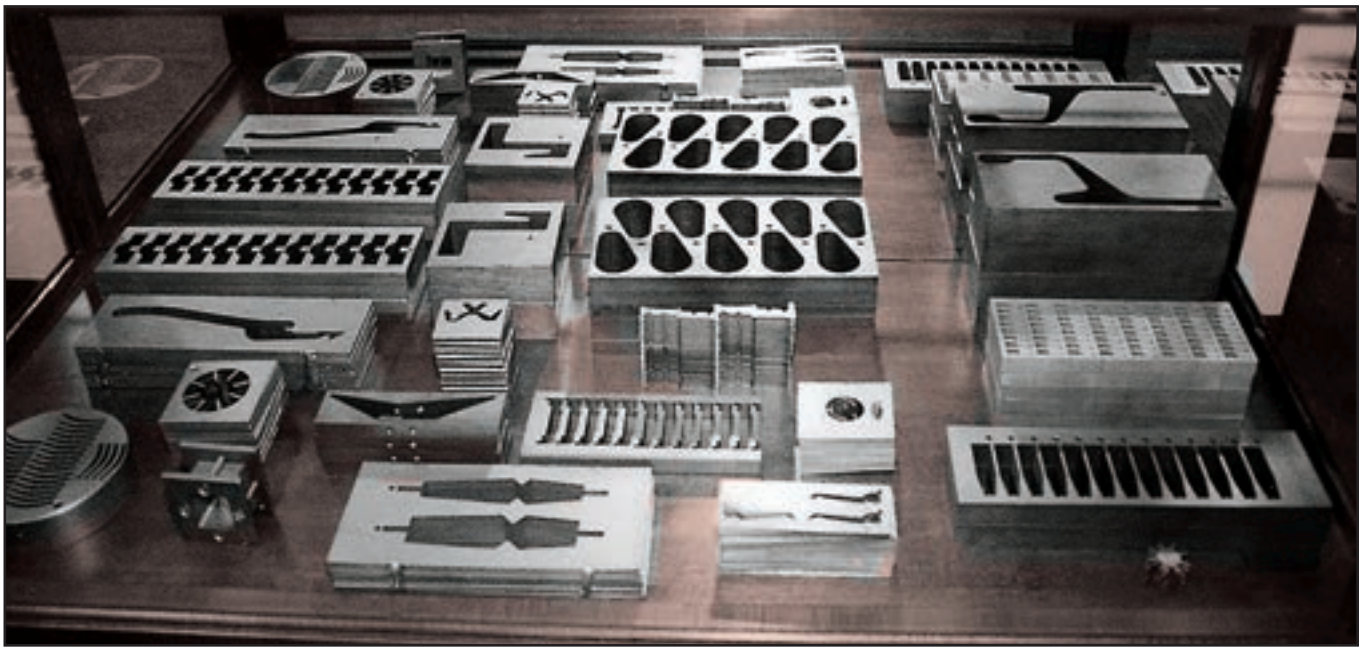


Figure 2:3

Wire EDM Production and Reliable's Display Cabinet Showing Various Production Jobs

Capabilities of Wire EDM

Some machines cut to accuracies of up to +/- .0001" (.0025 mm), producing surface finishes to 12 rms. At our company, we can cut parts weighing up to 10,000 pounds. See Figure 2:4 and 5 for some large and heavy parts.

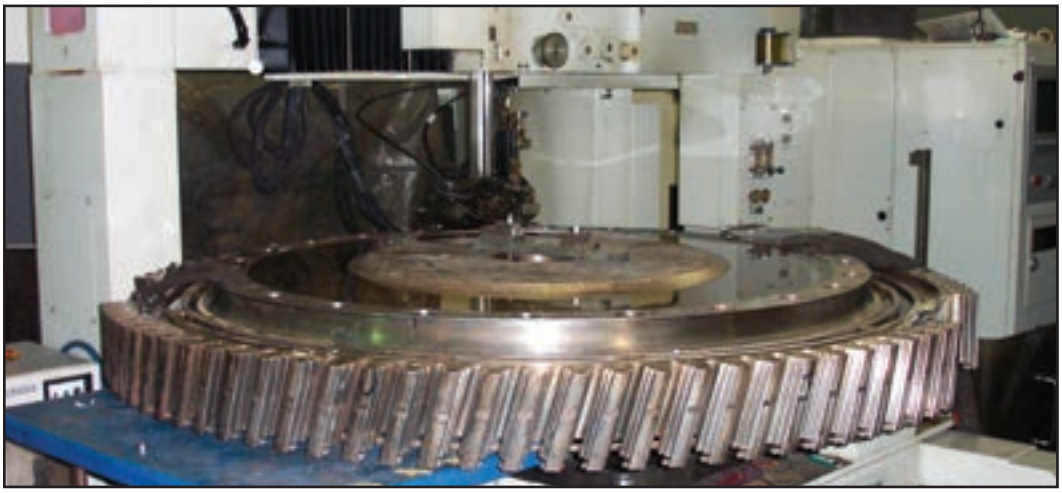


Figure 2:4

Wire EDM Machine Capable of Cutting Parts Up to 10,000 Pounds (Test Specimen Cut from a Turbine Measuring 7 Feet in Diameter)

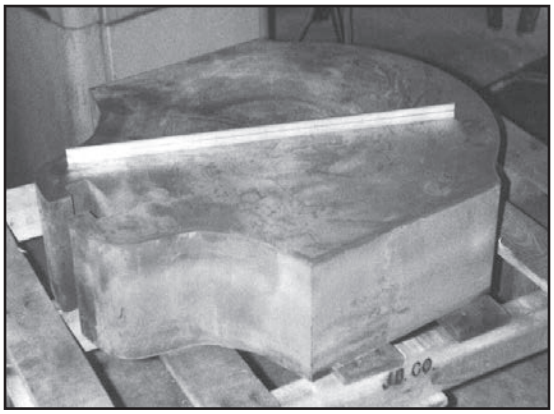


Figure 2:5

Large Gate Valve Wire EDMed—Ruler Is 24 inches (610 mm)

Wire EDM: a Serious Contender with Conventional Machining

Today, wire EDM competes seriously with such conventional machining as milling, broaching, grinding, and short-run stamping. Conventional wisdom suggests that wire EDM is only competitive when dealing with expensive and difficult-to-machine parts. But this is not the case. Wire EDM is often used with simple shapes and easily machined materials. Our company receives much work that could be machined by conventional methods. Although many of the customers have conventional CNC machines, they send their work to us to be EDMed.

A large wire EDM company reports their production runs up to 30,000 pieces take 65% of their cutting time. One particular job of theirs would have required fine blank tooling and a 10-12-week wait, but EDM was able to finish the hardened .062" (1.57 mm) thick stainless steel parts burr-free and on time for their production schedule.

New Demands by Design Engineers

As more design engineers discover the many advantages of wire EDM, they are incorporating new designs into their drawings. Therefore it becomes important for contract shops to understand wire EDM so they can properly quote designs requiring EDM.

An added benefit of wire EDM is that exotic alloys can be machined just as easily as mild steel. When wire EDM manufacturers select the optimum steel to demonstrate the capability of their machines, their choice is not mild steel, but hardened D2, a high-chrome, high-carbon tool steel.

Increasingly, today's drawings are calling for tighter tolerances and shapes that can be only efficiently machined with wire EDM. See Figure 2:6.

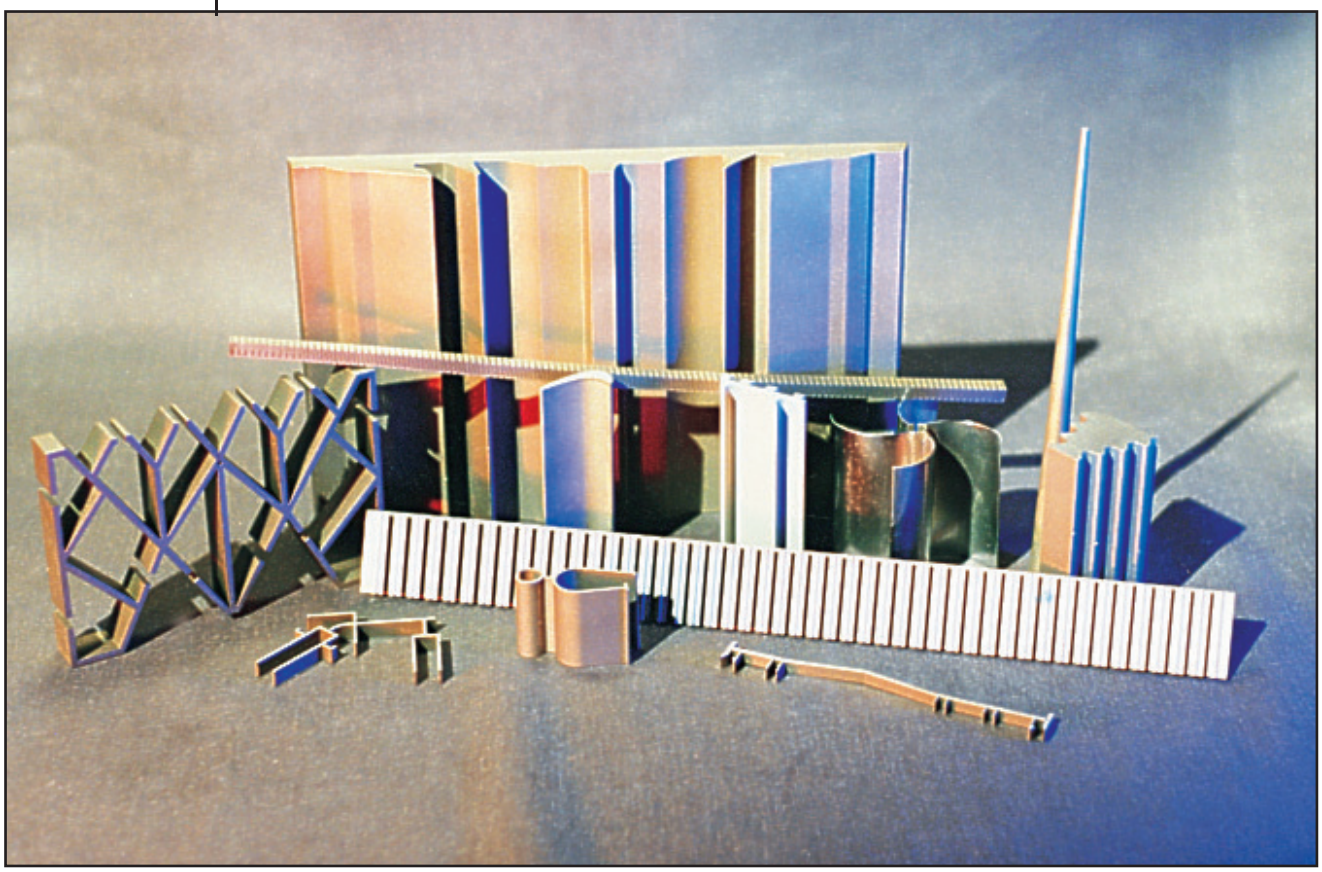


Figure 2:6

Various Shapes Cut with Wire EDM

Whether cutting with nozzles away from the workpiece, as in Figures 2:7 and 2:8, or with nozzles on the workpiece, wire EDM has proven to be one of the greatest machining revolutions.

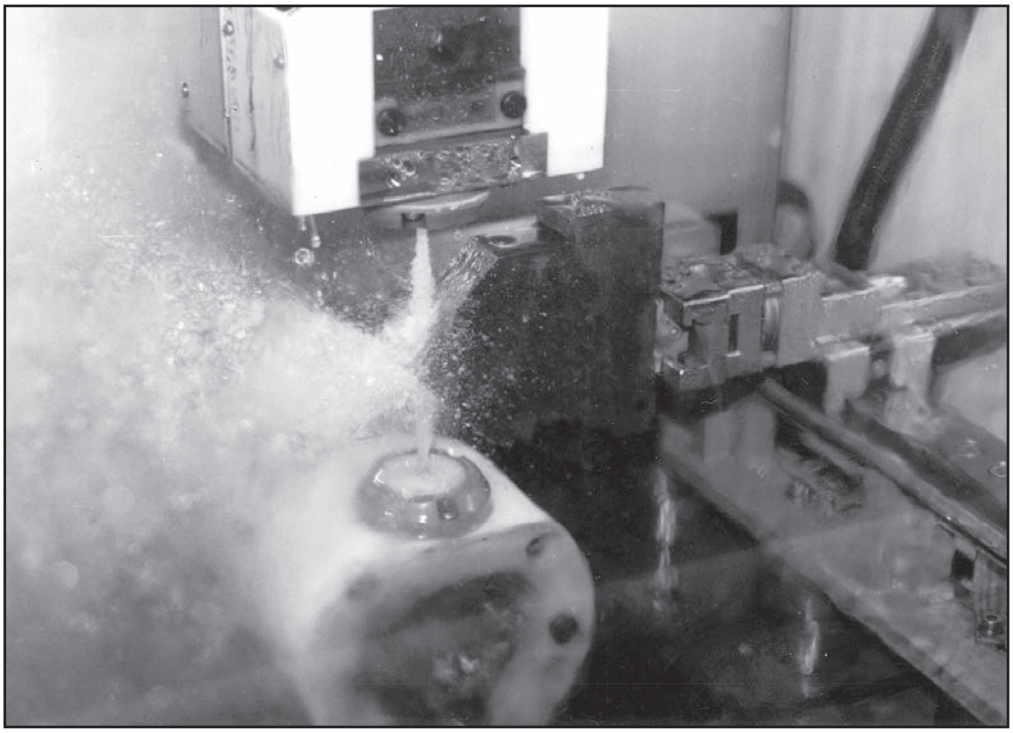


Figure 2:7

Cutting with nozzles away from the workpiece

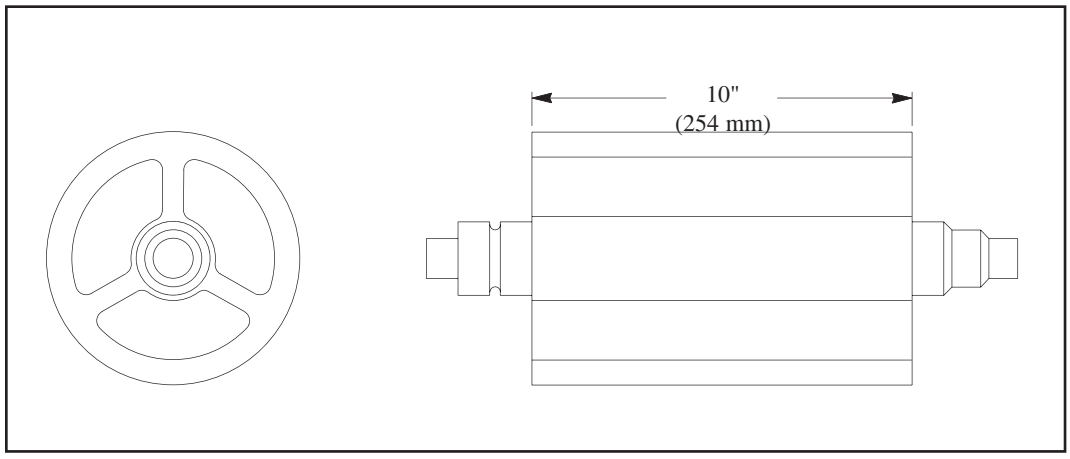


Figure 2:8

Cavities required to be cut in the air.

Fully Automated Wire EDMs

For total unattended operation, some wire EDM machines are equipped with automatic wire threading and robotized palletization. These machines are well equipped to do high production runs.

One company making standard and made-to-order punch and die sets for turret punch presses uses numerous wire EDM machines fed by a robot. The robot moves on a track between the two rows of wire EDM machines. After the parts are EDMed, a non-contact video inspection system, interfaced with a computer system, automatically examines the work.

General Electric uses 36 wire EDM machines to cut steam turbine bucket roots. Previously, GE used as many as 27 different operations, many of them milling; now it can cut the entire bucket periphery in one pass. Prior delivery with conventional methods required 12 weeks; wire EDM reduced the delivery to 2-4 weeks.

How Wire EDM Works

Wire EDM uses a traveling wire electrode that passes through the work piece. The wire is monitored precisely by a computer-numerically controlled (CNC) system. See Figure 2:9.

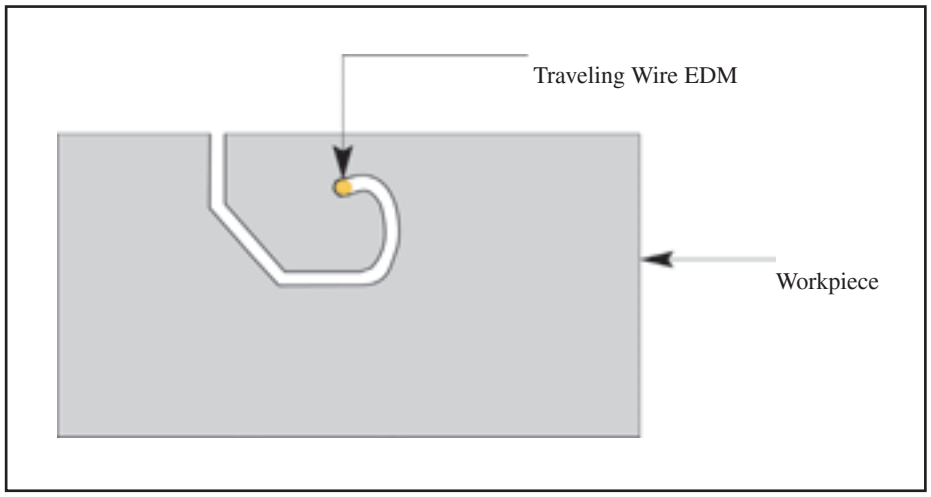


Figure 2:9
Wire EDM
The wire EDM process uses a wire electrode monitored by a CNC system to remove material.

Like any other machining tool, wire EDM removes material; but wire EDM removes material with electricity by means of spark erosion. Therefore, material that must be EDMed must be electrically conductive.

Rapid DC electrical pulses are generated between the wire electrode and the workpiece. Between the wire and the workpiece is a shield of deionized water, called the dielectric. Pure water is an insulator, but tap water usually contains minerals that causes the water to be too conductive for wire EDM. To control the water conductivity, the water goes through a resin tank to remove much of its conductive elements—this is called deionized water. As the machine cuts, the conductivity of the water tends to rise, and a pump automatically forces the water through a resin tank when the conductivity of the water is too high.

When sufficient voltage is applied, the fluid ionizes. Then a controlled spark precisely erodes a small section of the workpiece, causing it to melt and vaporize. These electrical pulses are repeated thousands of times per second. The pressurized cooling fluid, the dielectric, cools the vaporized metal and forces the resolidified eroded particles from the gap.

The dielectric fluid goes through a filter which removes the suspended solids. Resin removes dissolved particles; filters remove suspended particles. To maintain machine and part accuracy, the dielectric fluid flows through a chiller to keep the liquid at a constant temperature. See Figure 2:10.

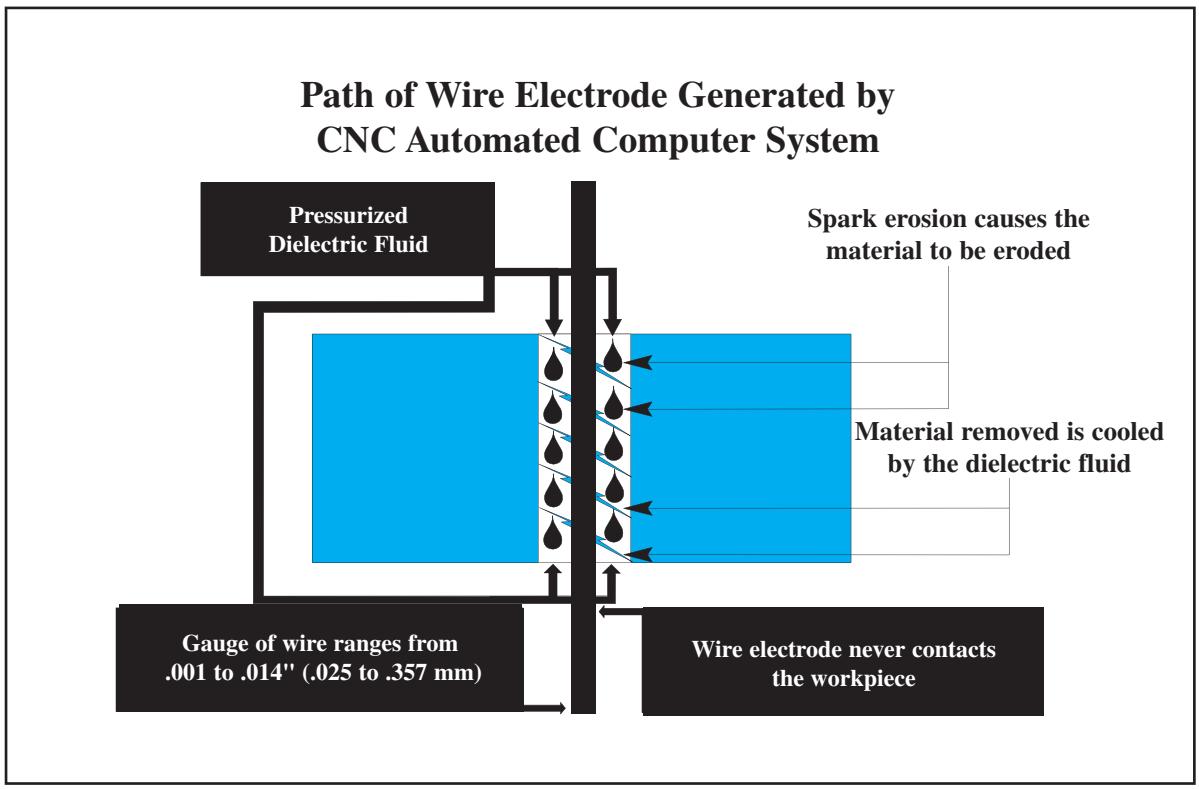


Figure 2:10

How Wire EDM Works
Precisely controlled sparks erode the metal using deionized water. Pressurized water removes the eroded material.

A DC or AC servo system maintains a gap from .002 to .003" (.051 to .076 mm) between the wire electrode and the workpiece. The servo mechanism prevents the wire electrode from shorting out against the workpiece and advances the machine as it cuts the desired shape. Because the wire never touches the workpiece, wire EDM is a stress-free cutting operation.

The wire electrode is usually a spool of brass, or brass and zinc wire from .001 to .014" (.025 to .357 mm) thick. Sometimes molybdenum or tungsten wire is used. New wire is constantly fed into the gap; this accounts for the extreme accuracy and repeatability of wire EDM.

The Step-by-Step Wire EDM Process

See Figures 2:11-14

A. Power Supply Generates Volts and Amps

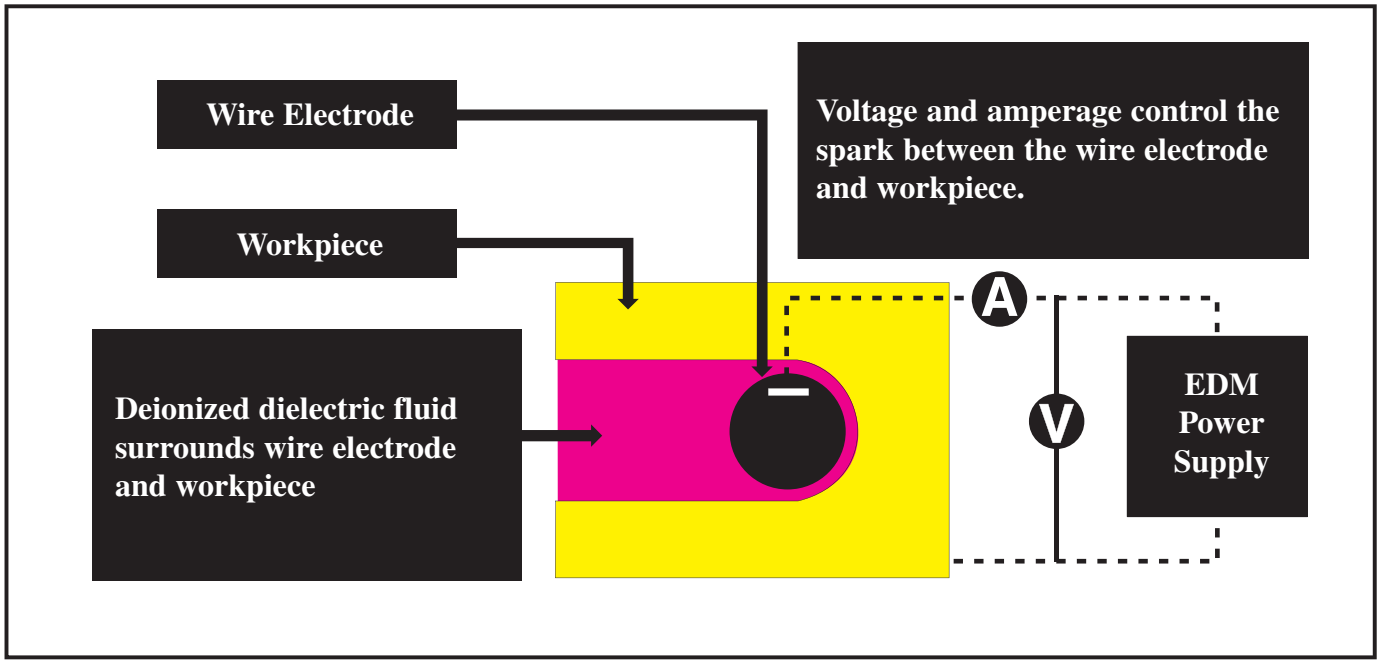


Figure 2:11

Deionized water surrounds the wire electrode as the power supply generates volts and amps to produce the spark.

B. During On Time Controlled Spark Erodes Material

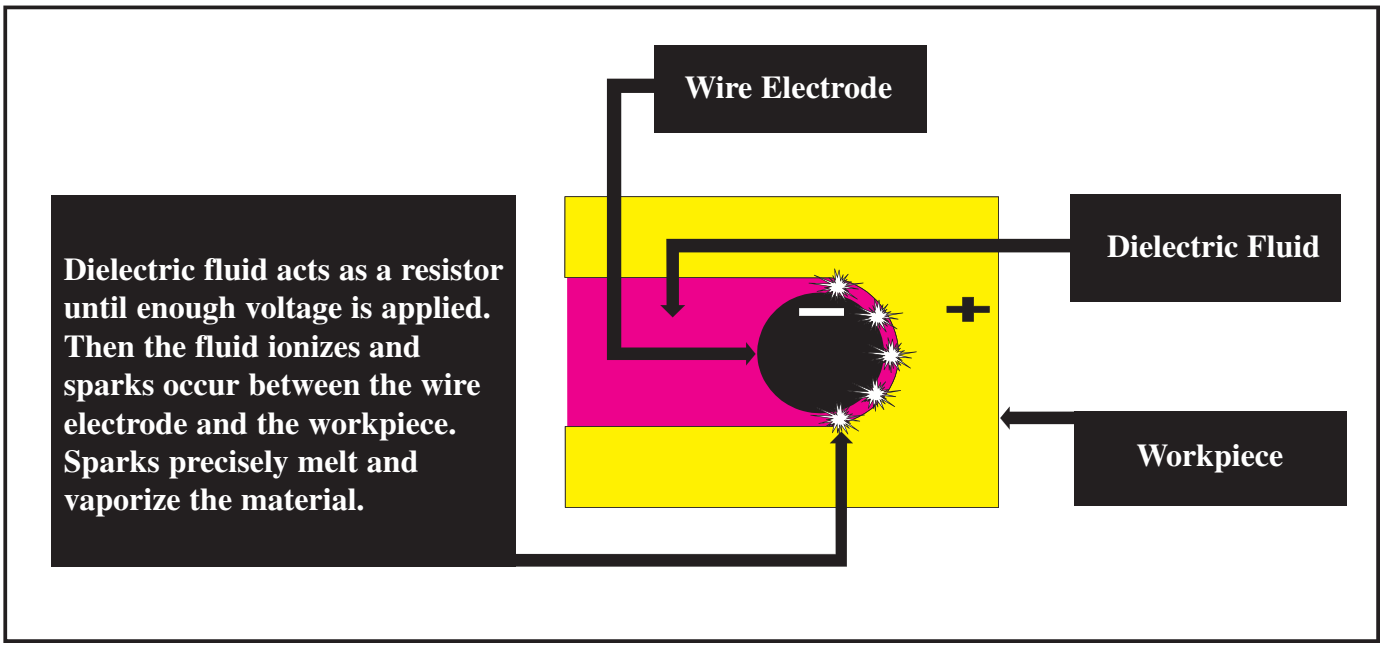


Figure 2:12

Sparks precisely melt and vaporize the material.

C. Off Time Allows Fluid to Remove Eroded Particles

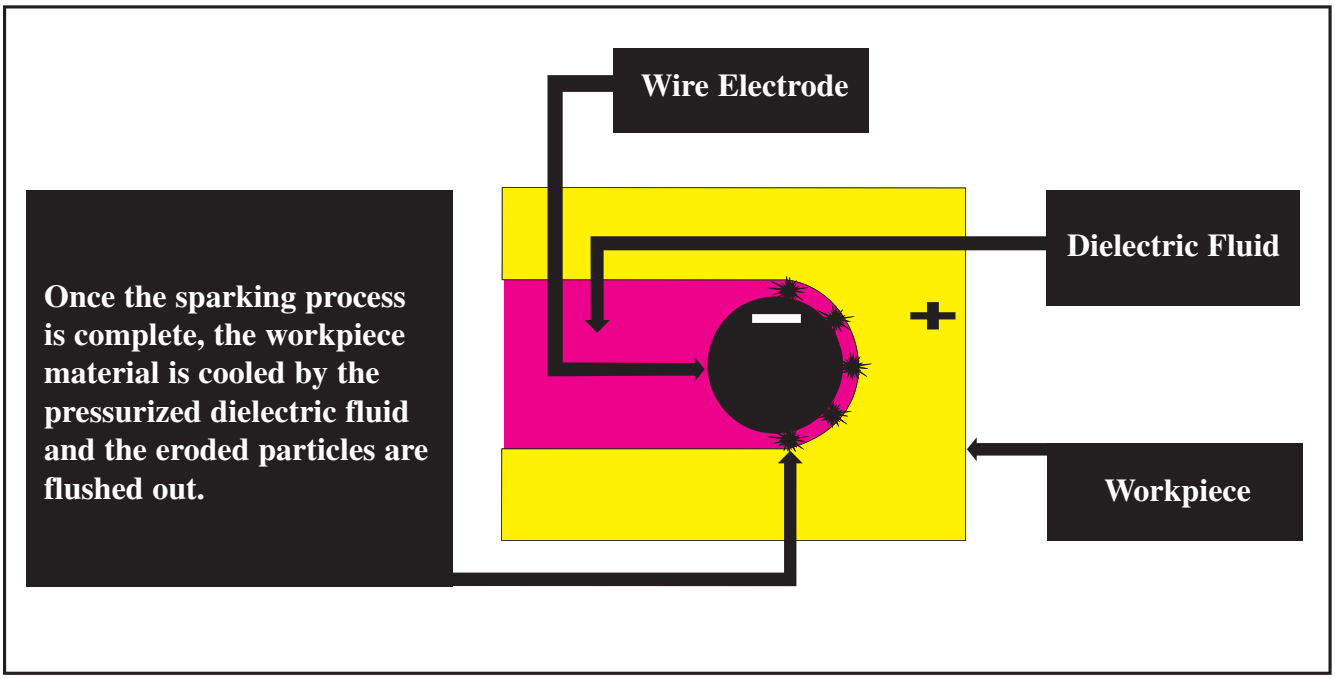


Figure 2:13

During the off cycle, the pressurized dielectric fluid immediately cools the material and flushes the eroded particles.

D. Filter Removes Chips While the Cycle is Repeated

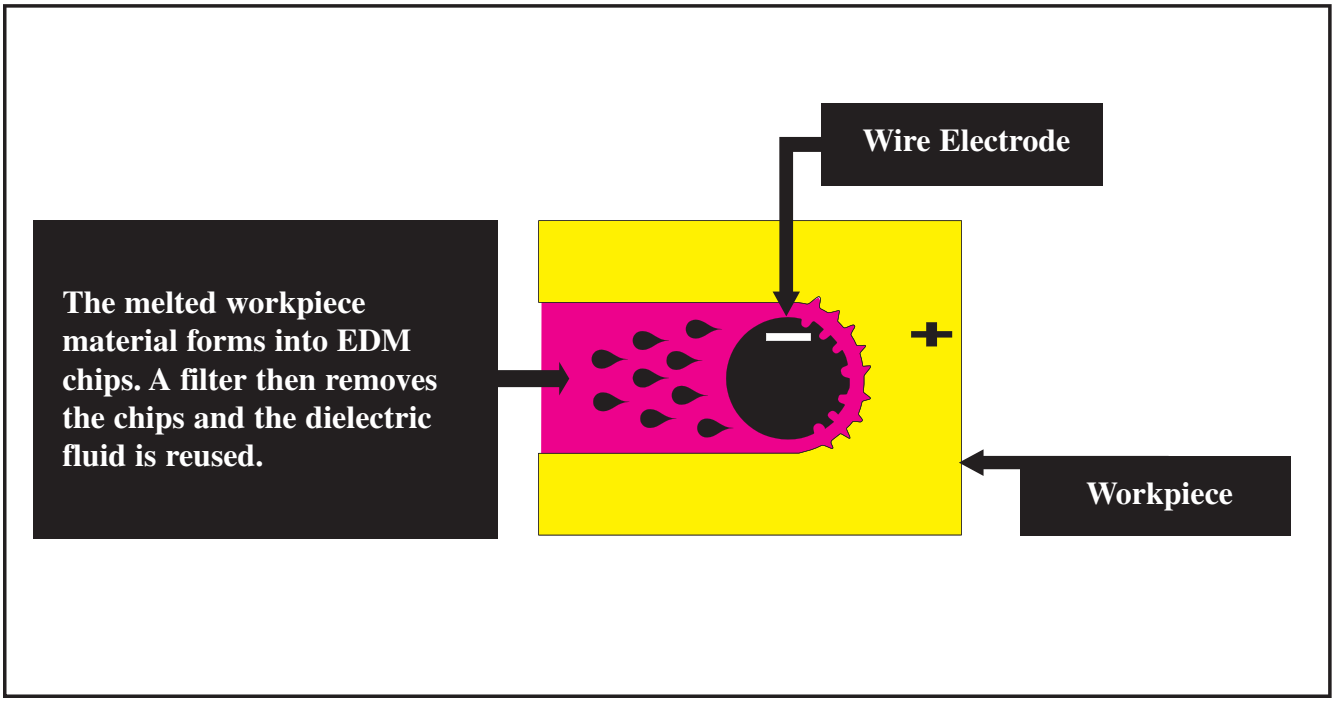


Figure 2:14

The eroded particles are removed and separated by a filter system.

Super Precision Band Saw

To better understand the wire EDM process, visualize the wire EDM machine as a super precision band saw with accuracies to +/-.0001" (.0025 mm). See Figure 2:15

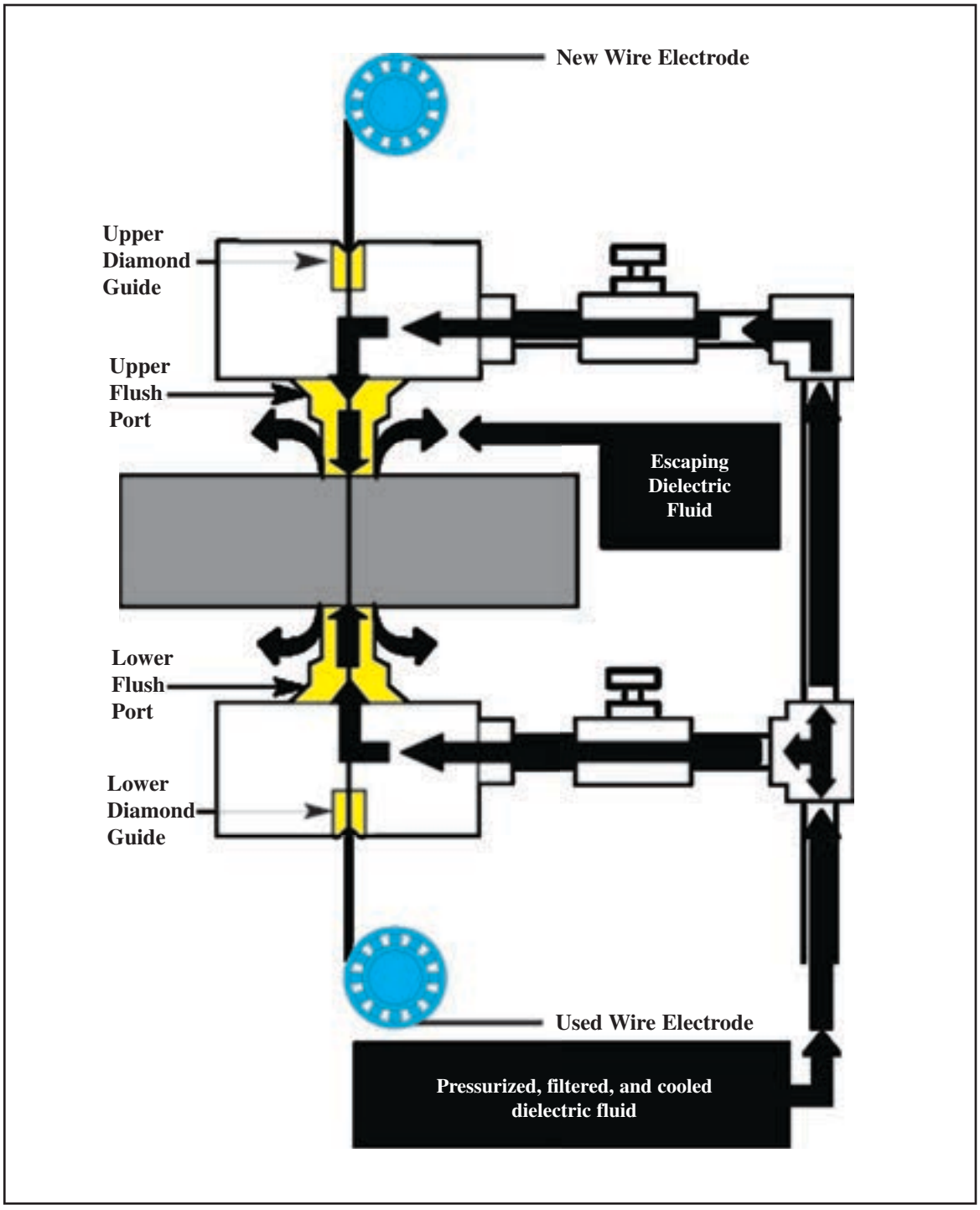


Figure 2:15

A super precision band saw capable of cutting hardened material to +/- .0001" (.0025 mm).

Independent Four Axis

Independent four axis wire EDM machines allow the machines to cut a top profile different from the bottom profile. See Figure 2:16. This is particularly useful for extrusion molds and flow valves.

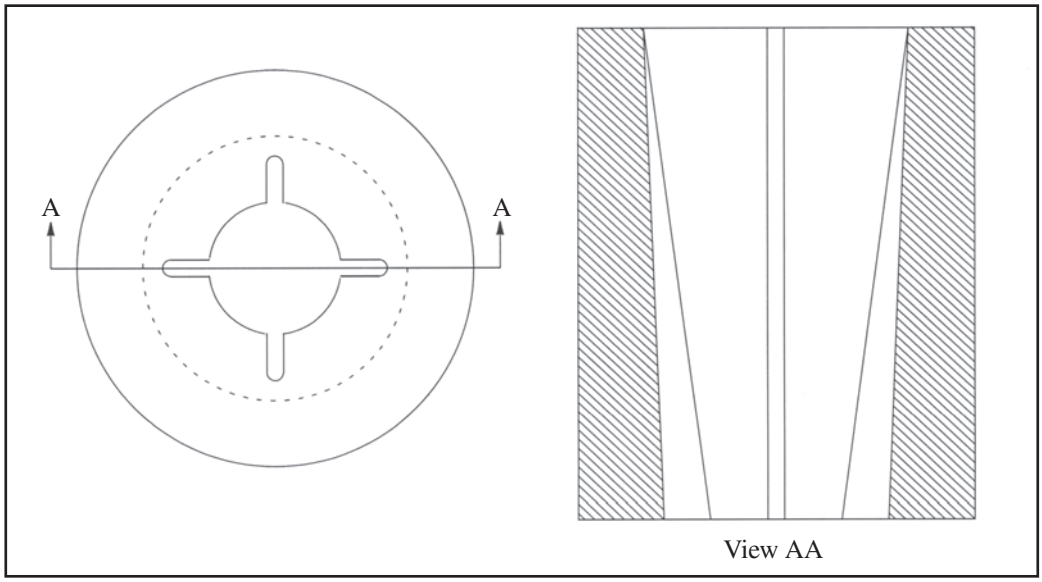


Figure 2:16

Independent Four Axis
Different shapes can be produced on top and bottom of a workpiece.

Parts as shown in Figure 2:17 were produced with independent four axis wire EDM.

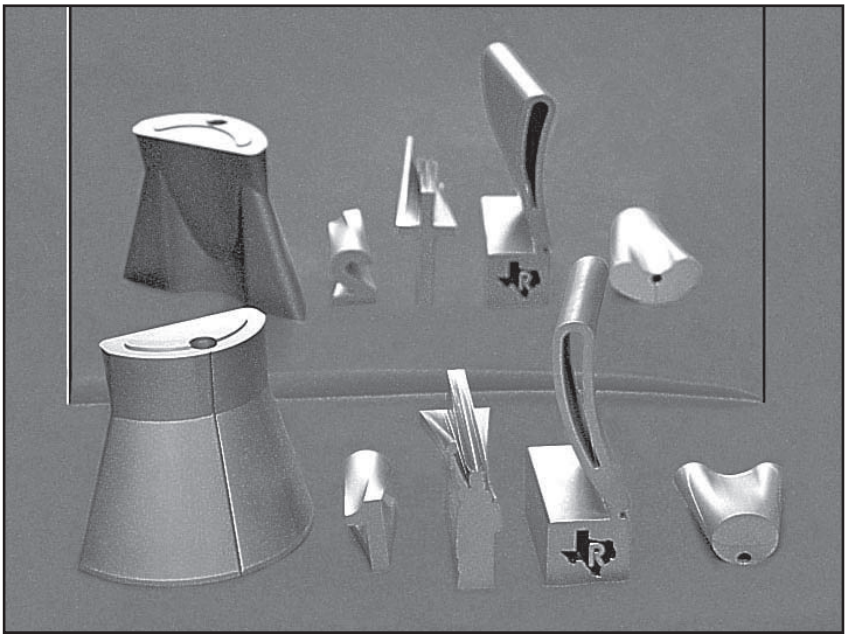


Figure 2:17

Independent Four Axis Parts

A computer image of the numbers one and two combined into a single piece is shown in Figure 2:18. (See the second image on the left on the previous page in Figure 2:17 for the EDMed number one and two.)

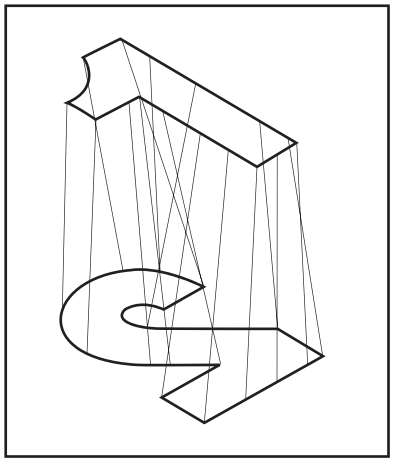


Figure 2:18

Programmed Number One and Number Two.

A picture of the Statue of Liberty combined with a Cross is shown in Figure 2:19, and the computer image in Figure 2:20. (To remove the Statue of Liberty and the Cross, various cuts had to be made in the scrap portion.)

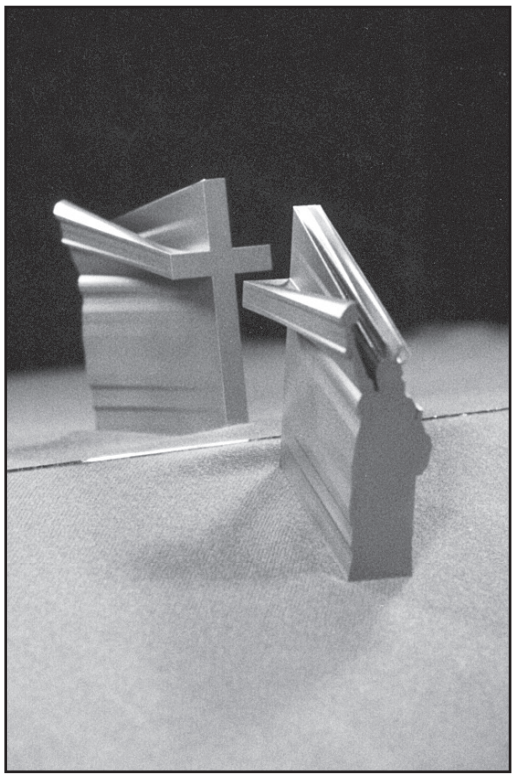


Figure 2:19

Statue of Liberty and Cross

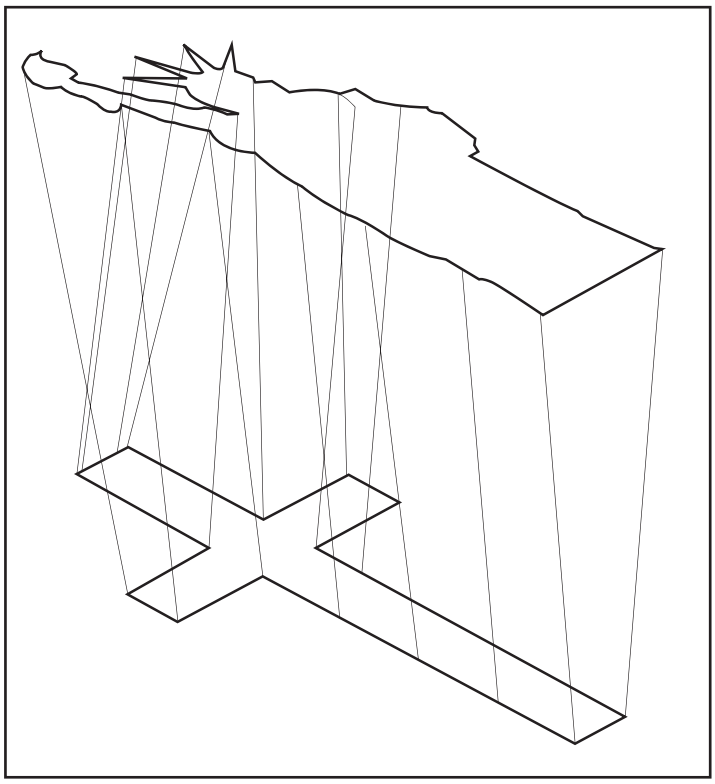


Figure 2:20

Computer Image of the Statue of Liberty and Cross.

Understanding Independent Four Axis

Manufacturers have discovered unique ways of using the capabilities of the independent four axis: extrusion molds, flow openings, injection molds, and many other complex shapes.

To better understand independent four axis, a person can hold a string and move the top and bottom of the string independently. Virtually any conceivable shape can be created within the confines of the travel of the U and V axis of the wire EDM machines. Machines are capable of cutting tall parts with independent angles up to 45 degrees. See Figure 2:21.

Courtesy Charmilles

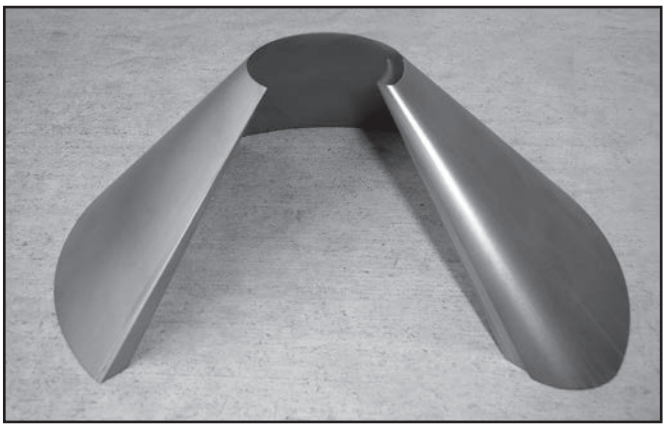


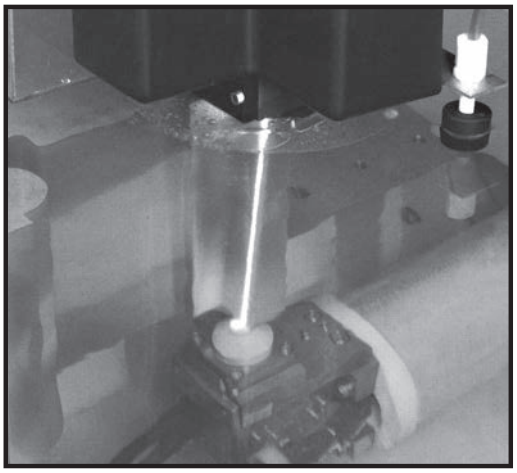
Figure 2:21

Wire EDM Machines are Capable of Cutting 45° Angles.

Submersible Cutting

In submersible cutting, a tank surrounds the work area, and the tank is filled with deionized water before the cutting takes place. In a dry machine, water needs to flow from the nozzles to surround the wire with deionized water.

Submersible cutting is a great aid in starting a cut and when skim cutting because the wire is always submersed in water, as shown in Figure 2:22. Dry machines can also do skim cutting, but one needs to be careful of always maintaining water around the wire, otherwise the wire will break. As shown in Figure 2:23, our company cut this 18" (457 mm) show piece submersed.



Courtesy Mitsubishi

Figure 2:22

A Submersible Wire EDM

Figure 2:23

Show Piece Cut Submersed—18" (457 mm)

Staying Competitive

To remain successful, companies need to keep informed of the newest technologies in order to remain competitive. Understanding the many changes in the EDM processes is important for those in manufacturing.

Engineering and trade schools should be concerned that their graduating students are properly equipped to enter the workforce knowing the latest technologies. This book aims to encourage and educate upcoming engineers, toolmakers, and those in management to understand and be able to use the EDM processes profitably.

In 1981, someone proved mathematically that wire EDM could not achieve speeds over 4 sq. in. (43 mm/min.) per hour. Those who experienced wire EDM in the early '80s may have decided that this process was inefficient and costly. Times have changed EDM dramatically.

Modifying Wire EDM Machines for Tall and Long Parts

The first wire EDM machines had heights between 2 to 4 inches (51 mm to 102 mm). Through the years, the cutting heights of EDM machines have increased. A customer came to Reliable EDM with a tall part and was told we couldn't cut the part because of the height limitations of our machines. Carl Sommer happened to pass by as the customer was told they could not cut the part. Since Carl has years of machining experience and has worked on building machines, he thought they could modify a machine to cut the part. Today, they can EDM parts weighing up to 10,000 pounds and workpieces up to 64 inches (1626 mm) tall. Illustrated in Figure 2:24 are some tall parts our company has EDMed. The moral of the story—let your imagination run wild.

Figure 2:24

Various Tall Parts EDMed
We have modified a wire EDM machine to cut parts up to 64" (1626 mm) tall.

A customer came to us and wanted to split a 27-inch (656mm) tube that was 16.5 feet (5.03m) long with wire EDM. We did not have the capability. Then we got an idea, and modified one of our EDMs. See Figure 2:25.

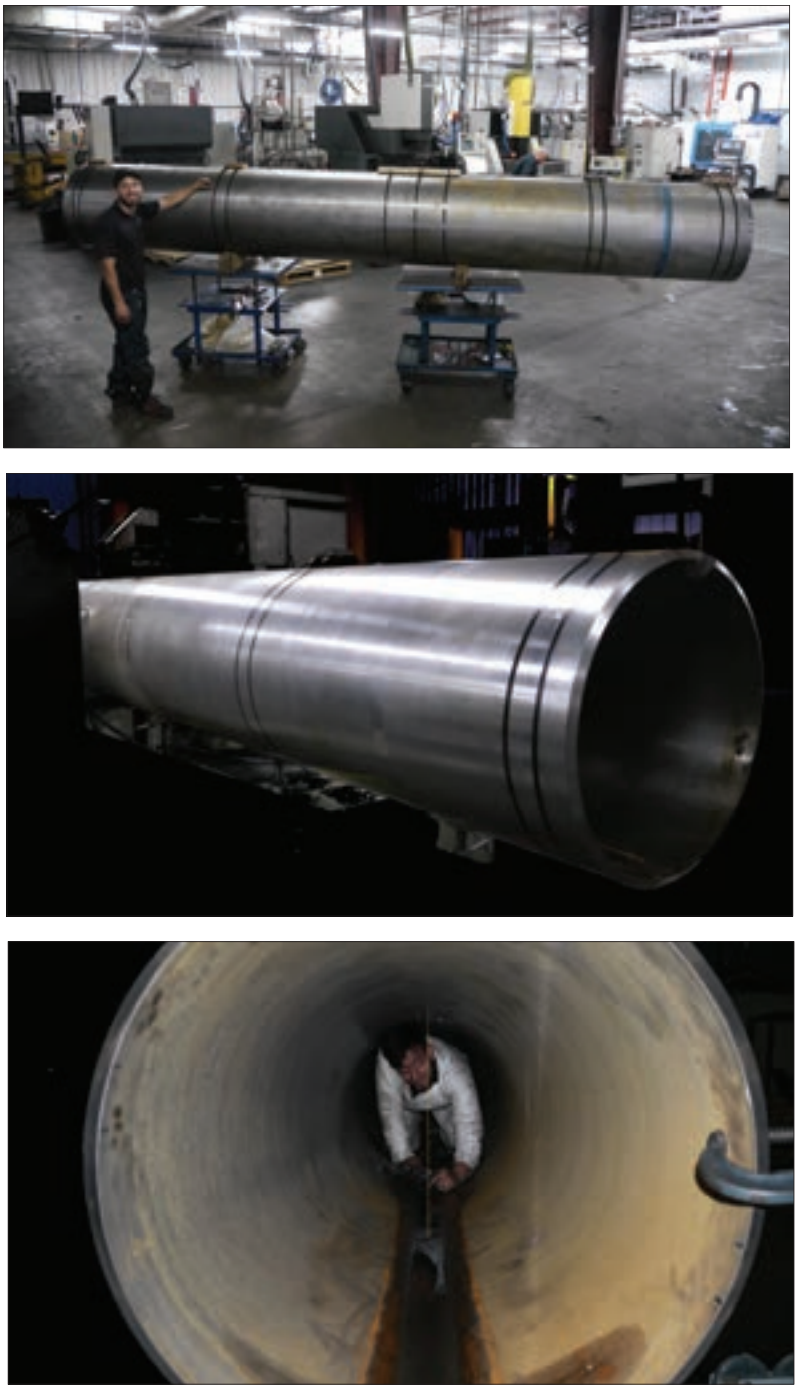


Figure 2:25

Modified Wire EDM Machine to Split Large Tube Diameter 27 Inches (656mm), Length 16.5 Feet (5.03m)

We have examined the fundamentals of wire EDM. Let us now examine some of the many ways one can profit with this revolutionary machining process.

Free Training Videos (ReliableEDM.com)

How Wire EDM Works: Part 1 (6:11)

How Wire EDM Works: Part 2 (8:01)

Capabilities of Wire EDM: Part 1 (7:48)

Capabilities of Wire EDM: Part 2 (9:37)

EDMing Tall and Large Parts (7:25)