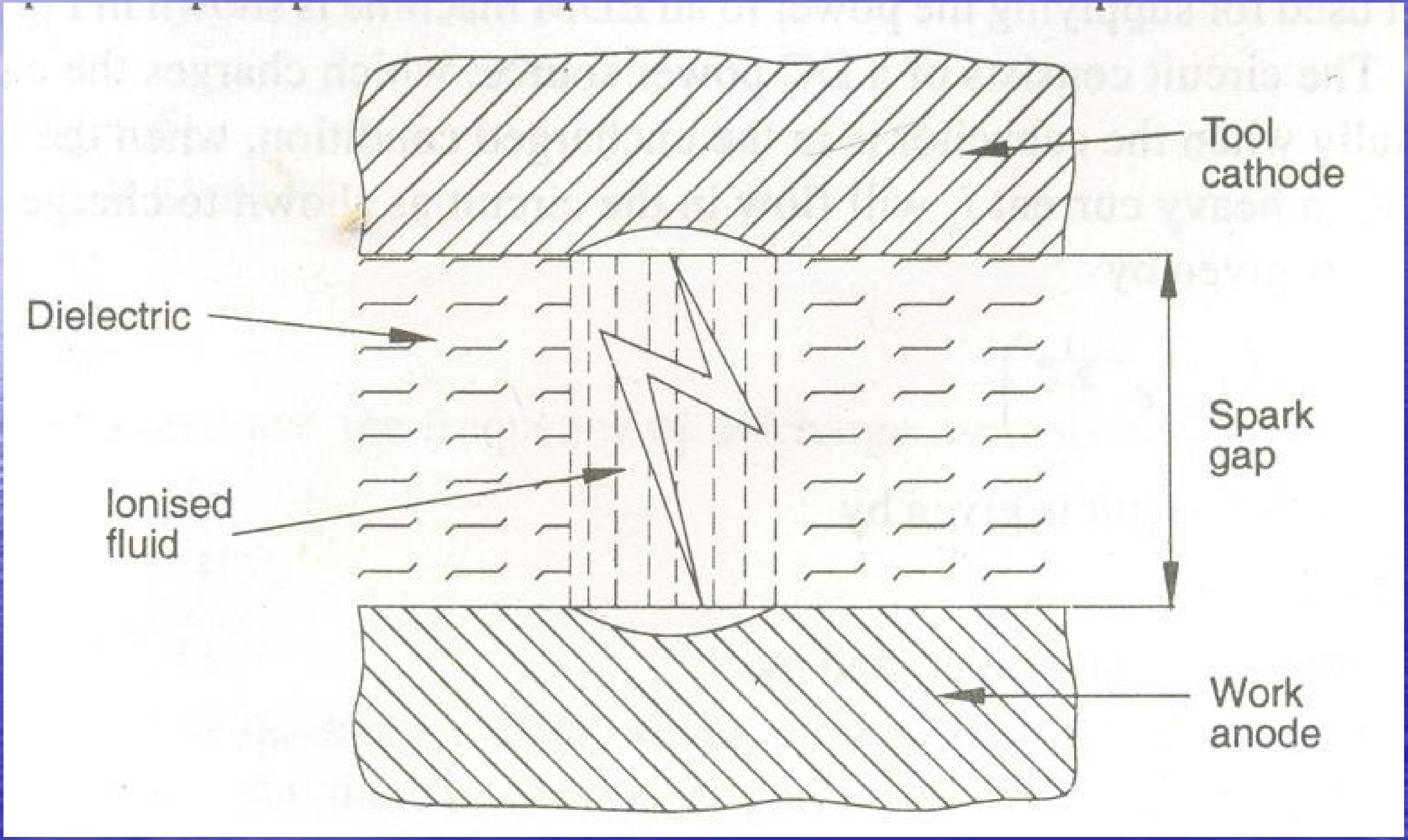
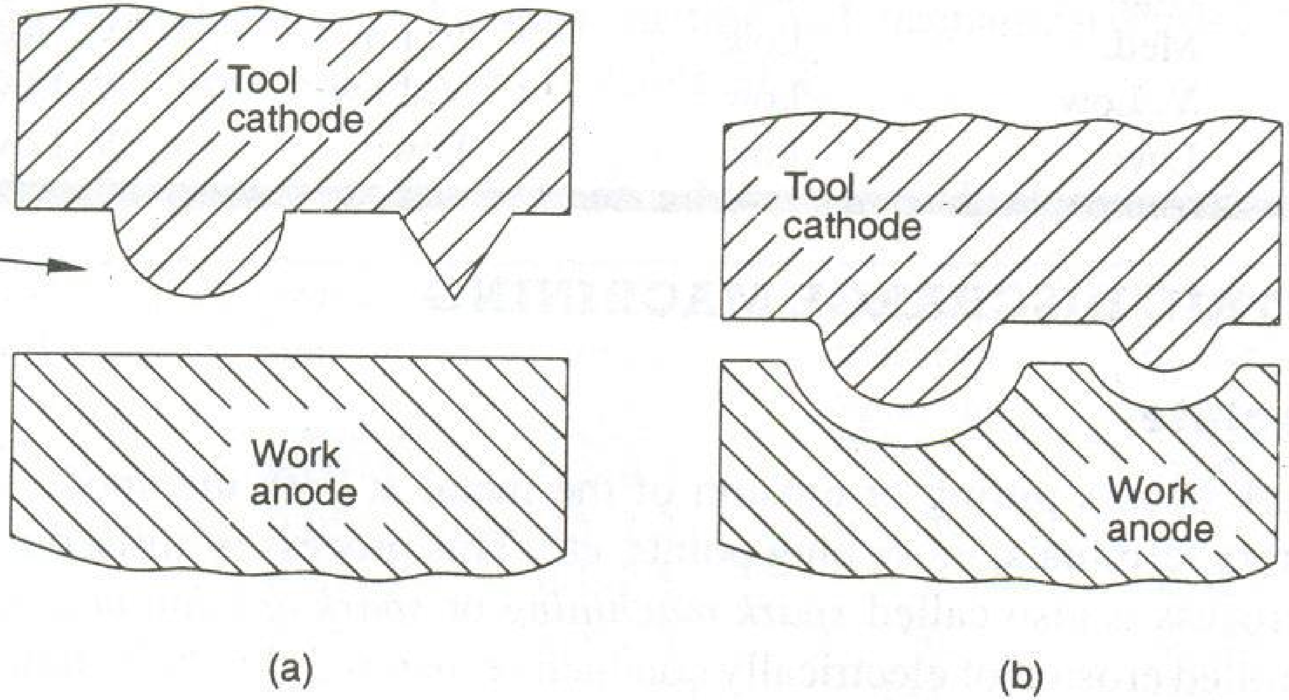
Unit 3 - EDM

Synopsis

- Working principle
- Equipments
- Process parameters
- MRR
- Electrode / Tool
- Power circuits
- Tool wear
- Dielectric
- Flushing
- Advantages
- Limitations
- Applications
- Wire cut EDM
- Recent trends in EDM

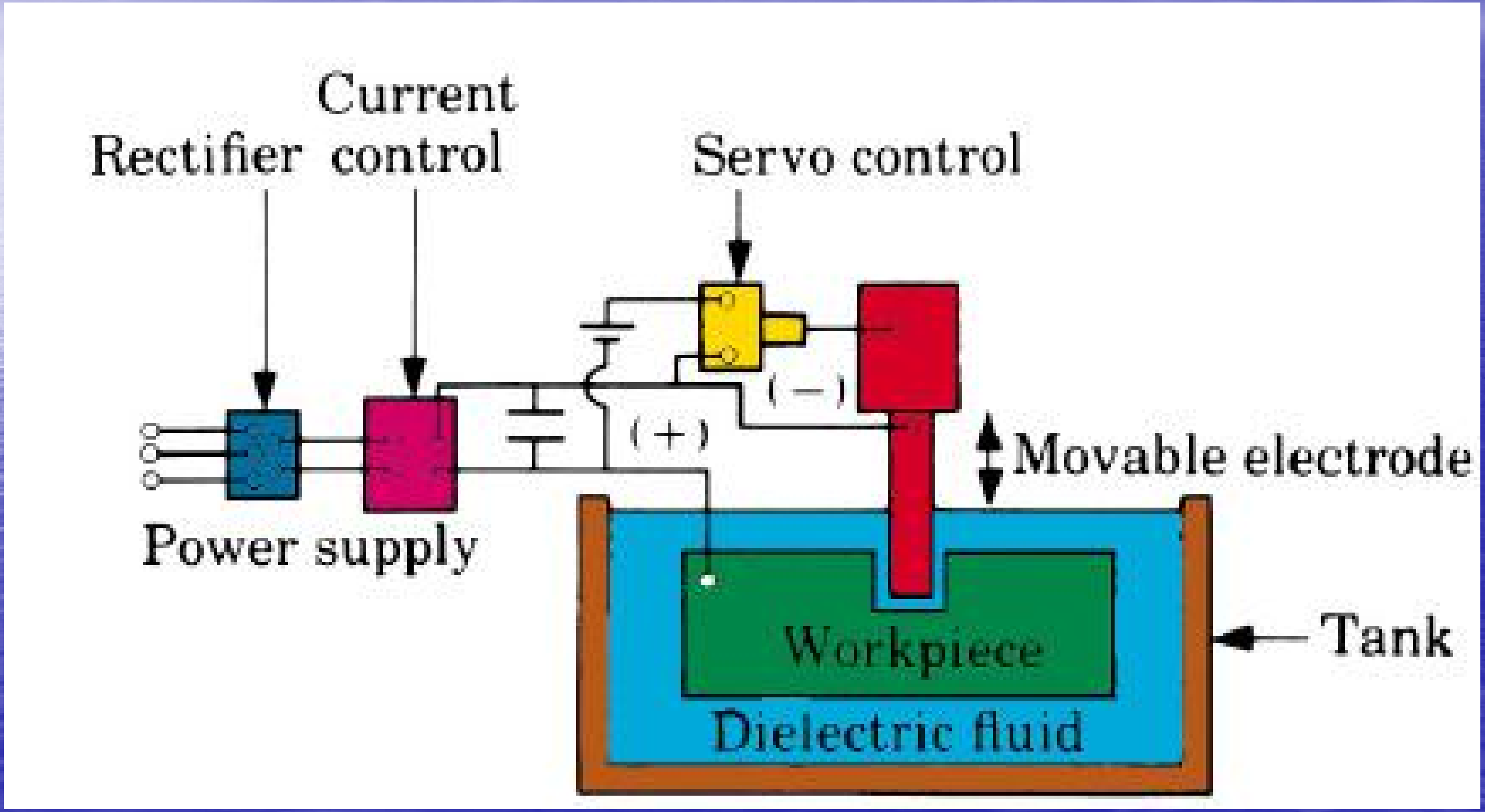
Working principle





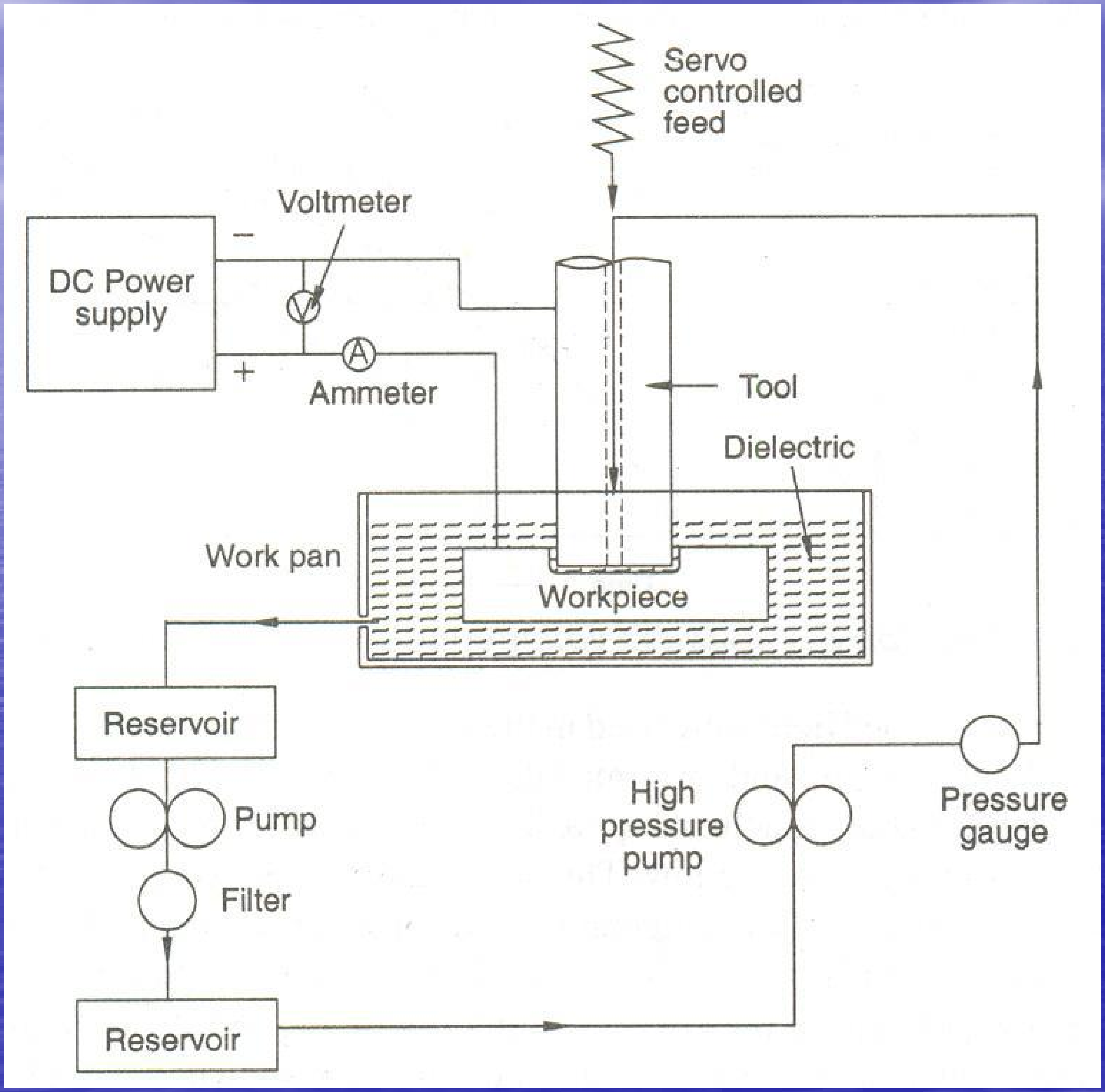
Typical surface generation in EDM process, (a) Initial shape of electrode and workpiece, (b) Final complimentary shapes of electrode and workpieces after machining

EDM Setup

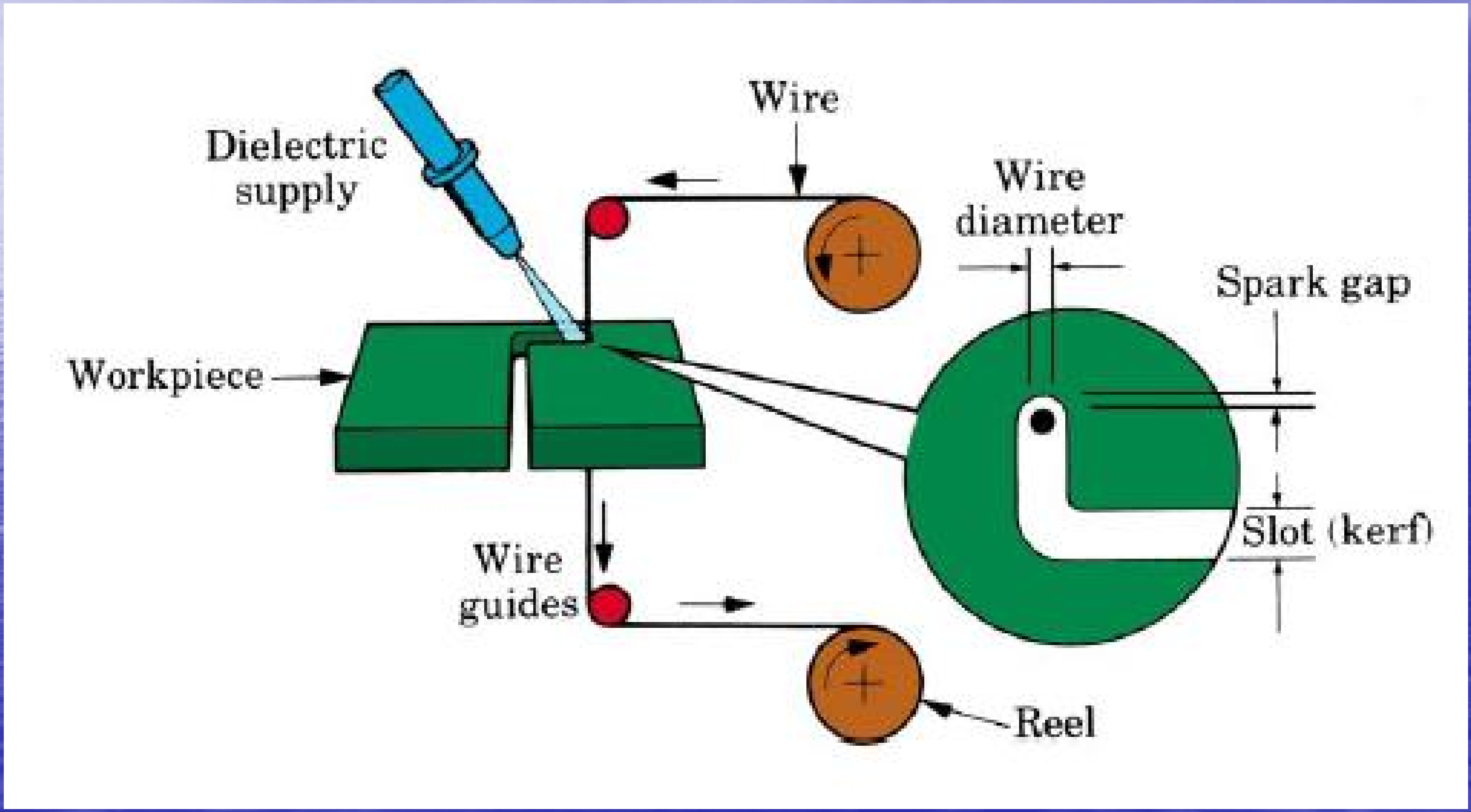


Current control
Rectifier
Servo control
(−)
(+)
Movable electrode
Power supply
Workpiece
Tank
Dielectric fluid

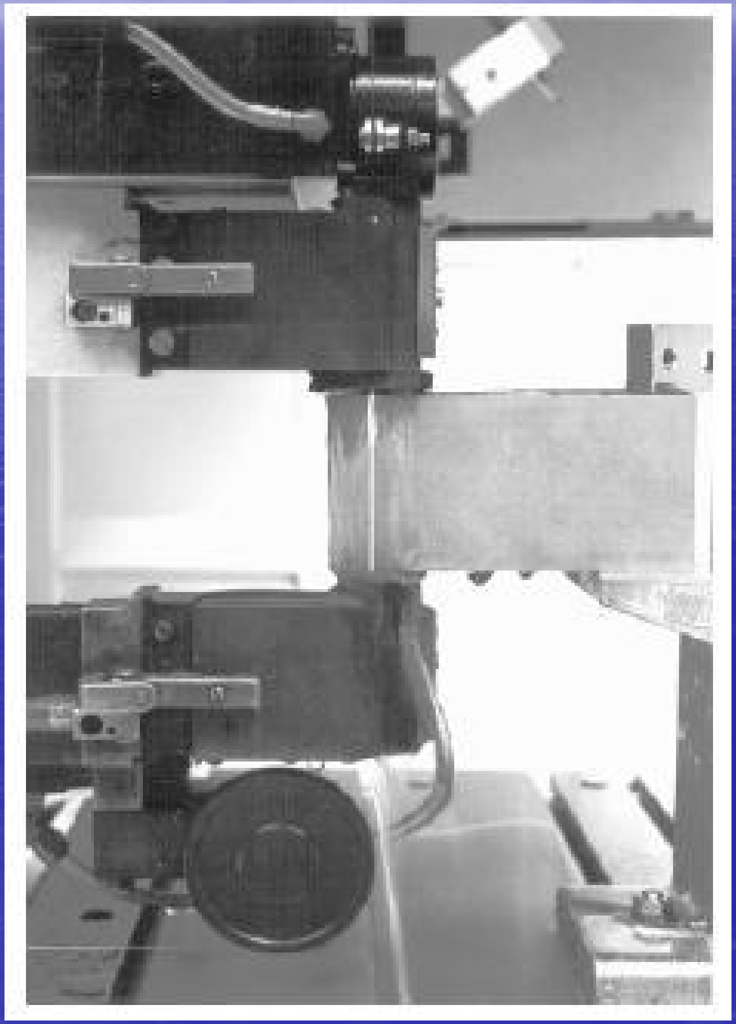
Components of a typical EDM machine



WEDM setup


Wire
Dielectric supply
Wire diameter
Spark gap
Workpiece
Slot (kerf)
Wire guides
Reel

WEDM setup



Theories for material removal

- High pressure theory – sudden stoppage of electrodynamic waves, high impulsive pressure released – expected plastic deformation not found
- Static field theory – the electrostatic force (Coulomb's law) between the electrodes produce stress on the electrodes resulting in tensile rupture – does not explain for durations greater than a few microseconds
- High temperature theory – due to the bombardment of high energetic electrons on the electrode surface, the spot attains high temperature – predominating one

Requirements of a dielectric fluid

An ideal dielectric fluid should have the following properties:

- sufficient and stable dielectric strength
- de-ionize rapidly
- low viscosity and good wetting capacity
- Chemically neutral
- Flash point should be high
- Not emit toxic vapours or have unpleasant odour
- Maintain these properties in varying temperatures, contamination by wear debris and products of decomposition
- Economical and easily available

Commonly used dielectric fluids

- Hydrocarbon fluids – transformer oil, paraffin oil, kerosene, lubricating oils
- Silicone based oils
- De-ionized water

Flushing

- Method in which the dielectric fluid flows between the tool and the work gap
- Efficiency of machining depends to a greater extent on the efficiency of flushing
- Choice of flushing method depends upon the workpiece size and geometry
- Methods of flushing

1. Suction
2. Pressure
3. Jet
4. Alternating forced flushing
5. Ultrasonic vibration of electrodes
6. Rotating electrode flushing

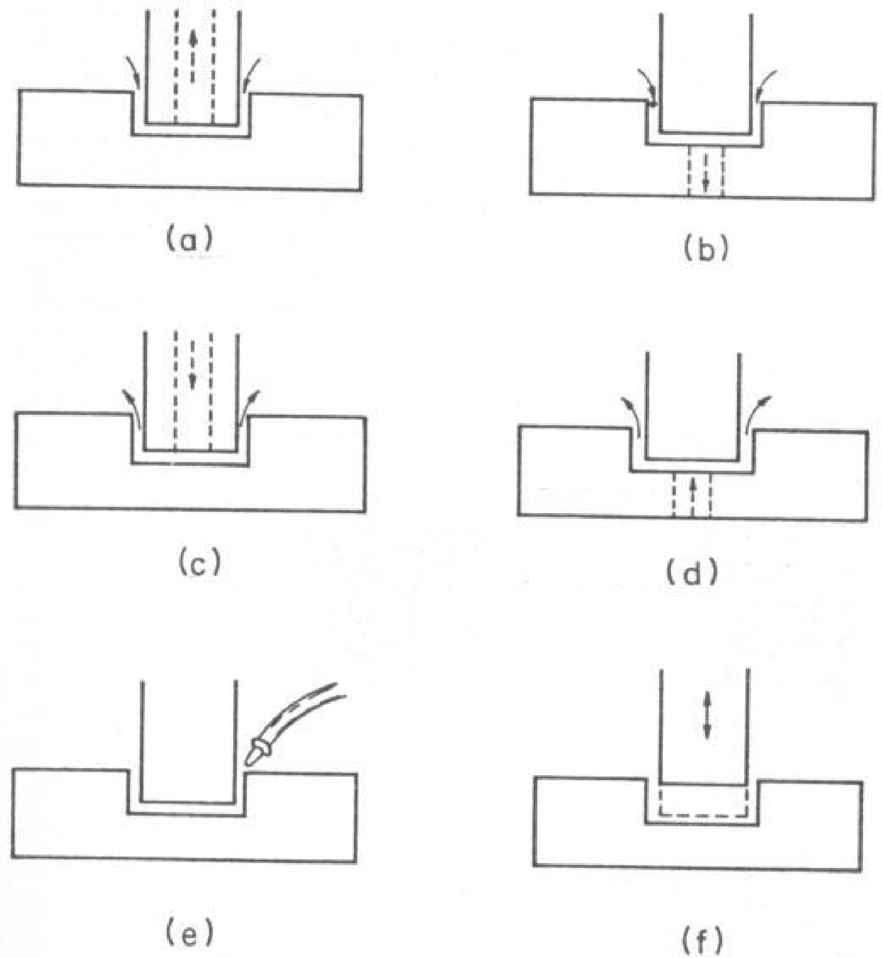


Fig. 7.7 Various methods for dielectric flushing: (a) suction through electrode, (b) suction through workpiece, (c) pressure through electrode, (d) pressure through workpiece, (e) jet flushing, (f) periodic cycling of electrode [*HMT, Bangalore, Catalogue*].

Need for filtering

- To avoid changes in insulation qualities
- Increase in the pollution of dielectric results in decrease in the breakdown intensity of the field
- Affects the reproduction accuracy of the process

Electrodes

An ideal electrode material should have the following characteristics to serve as a good tool:

- Good conductor of electricity and heat
- Easily machinable to any shape at a reasonable cost
- Produce efficient MRR from the workpieces
- Resist the deformation during the erosion process
- Exhibit low electrode (tool) wear rates
- Available in a variety of shapes

Electrode materials

- Graphite
- Copper
- Copper graphite
- Brass
- Zinc alloys
- Steel
- Copper tungsten
- Silver tungsten
- Tungsten etc.,

Methods used for making the electrodes: conventional machining, casting, metal spraying and press forming

Table 11.5 ***Electrode material selection***

Electrode Material	*Form*	*Corner wear ratio in finishing*	*End wear ratio in roughing*	*Relative cost*	*Machinability rating*	*Uses*	
						Recommended	*Not Recommended*
Graphite	Block, rod, tube, bar	5:1	to 100:1	low	excellent	Tooling	–
Copper	Bar, rod, sheet, wire, tube, forgings, stampings	1:1	2:1	medium	good	holes, slots	high accuracy and detail
Copper-Graphite	Blocks, rods	2:1	4:1	medium	fine	general purpose	–
Brass	Same as copper	0.7:1	1:1	low	good	holes and cavity sinking	high accuracy
Zinc alloys	Cast, die casting	0.7:1	2:1	low	good	forging die cavities	holes
Steel	all forms	1:1	2:1	low	excellent	through holes	carbides
Copper Tungsten	bar, flats, shim stock, rod, wire, tube	3:1	8:1	medium	fair	slots, carbides	large areas
Silver Tungsten	sintered	8:1	12:1	high	fair	small slots, holes and intricate details	large areas
Tungsten	wire,rod, ribbon	5:1	10:1	high	poor	small holes	irregular holes

Tool wear

1. Need for tool wear knowledge:
- Essential for determining the electrode size and number of electrodes – economics
2. Definition of Tool wear: Partial removal of the tool material form the tool surface while machining the workpiece due to the discharge spark produced between the tool and the workpiece
3. How it takes place - Due to the sparking action, the intense heat generated near the zone melts and evaporates the materials in the sparking zone.
4. Tool wear can be minimized by using a tool material that has a high melting point and high thermal conductivity. Also by properly configuring the tool design, tool wear can be minimized
5. Wear ratio: ratio of the material removed from the work to the material removed from the tool
6. Electrode wear is a function of factors such as:
- Polarity
- Thermal conductivity
- Melting point of electrode
- Duration and intensity of spark discharges
- Types of power supplies used
- Type of work material used in relation to the tool material
- Dielectric flow in the machining zone
7. Graphite has very high melting point (3727°C). It does not melt rather vaporizes. At the same time, the tool wear is minimum.

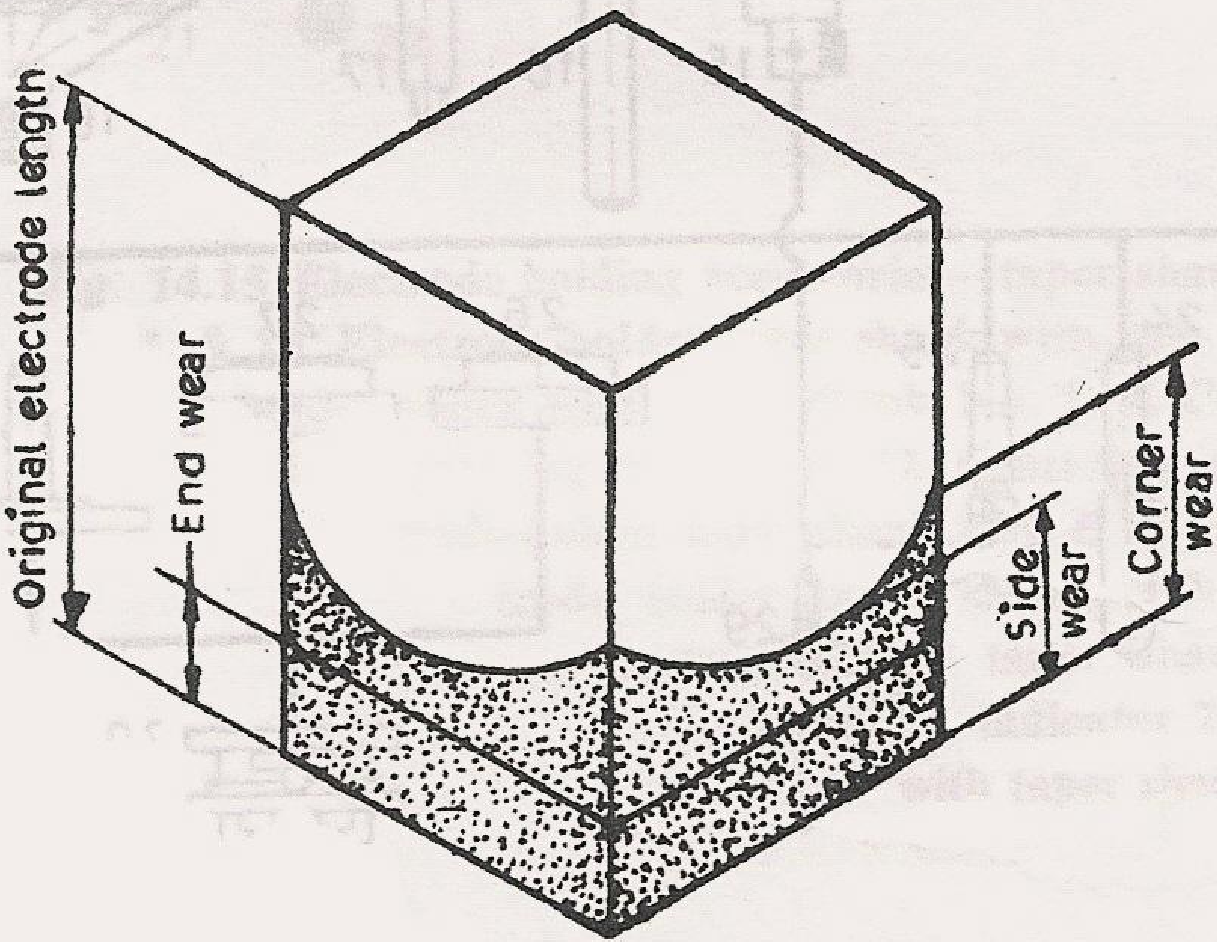


Fig. 14.13 Methods of measuring electrode wear

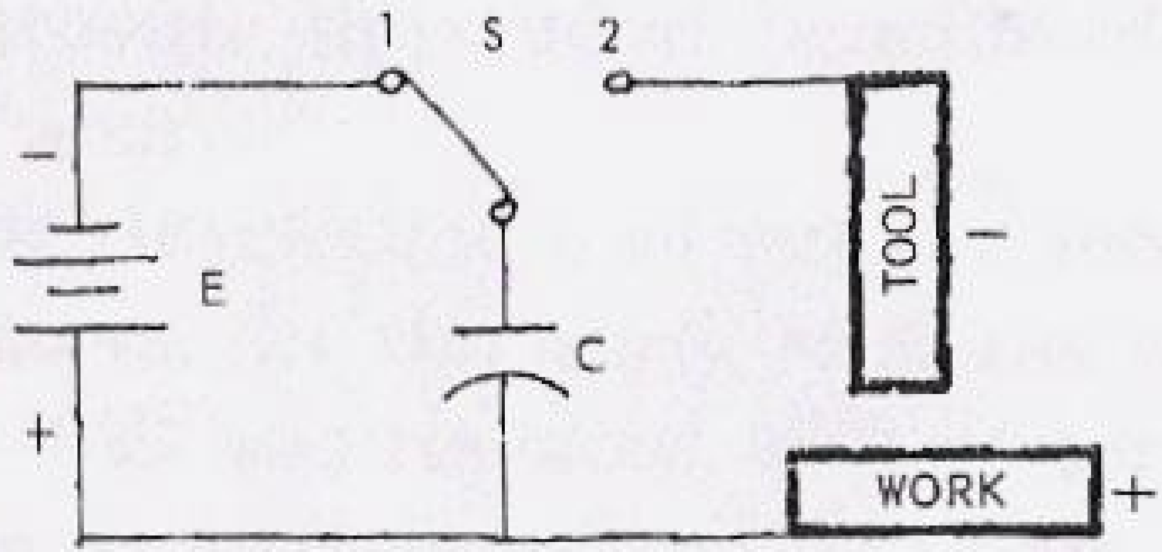
Power generator circuits

Functions:

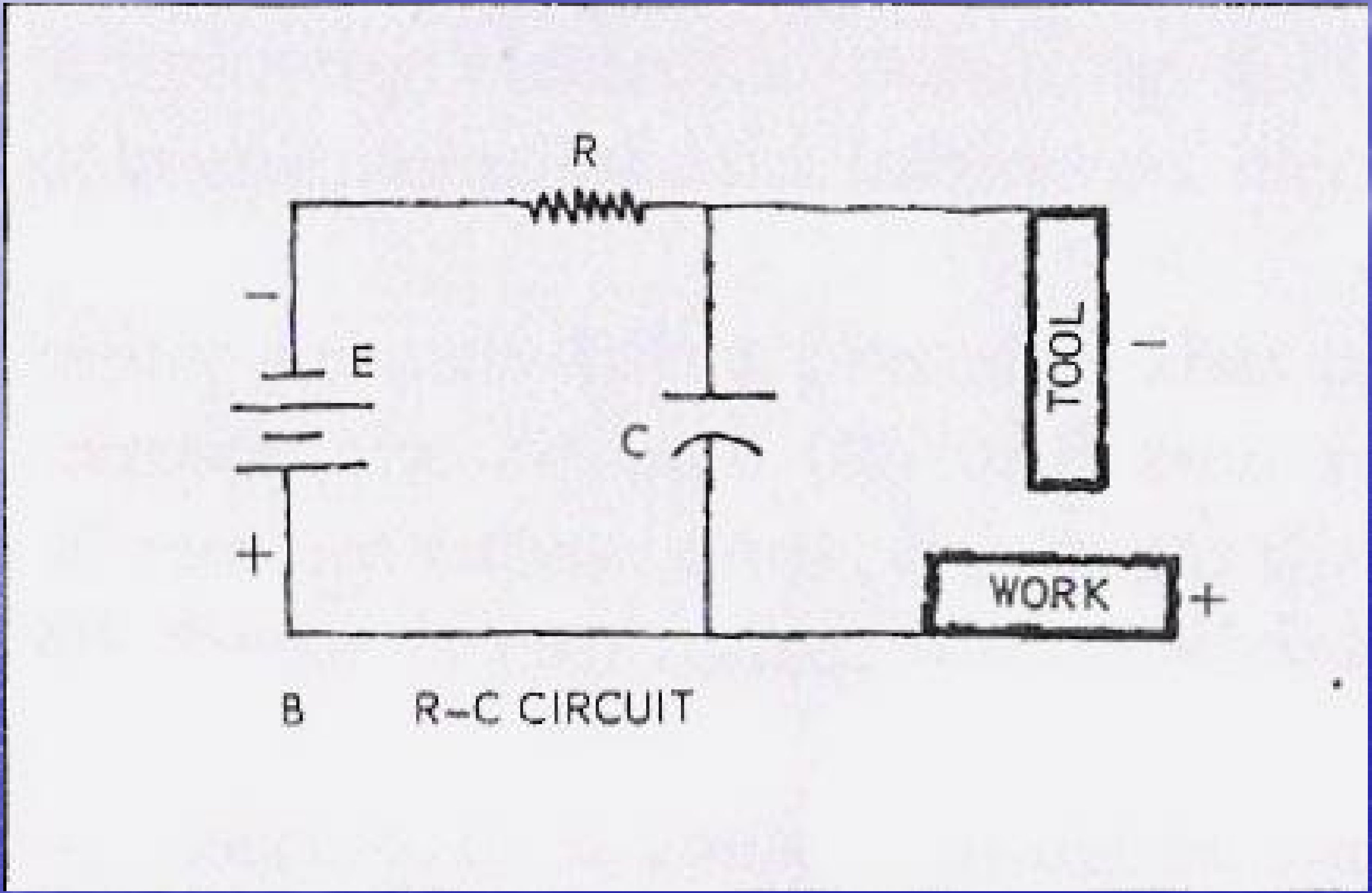
- To supply adequate voltage to initiate and maintain the discharge
- To adjust the discharge current intensity
- To adjust the discharge duration
- To control recurring rhythm of the discharge

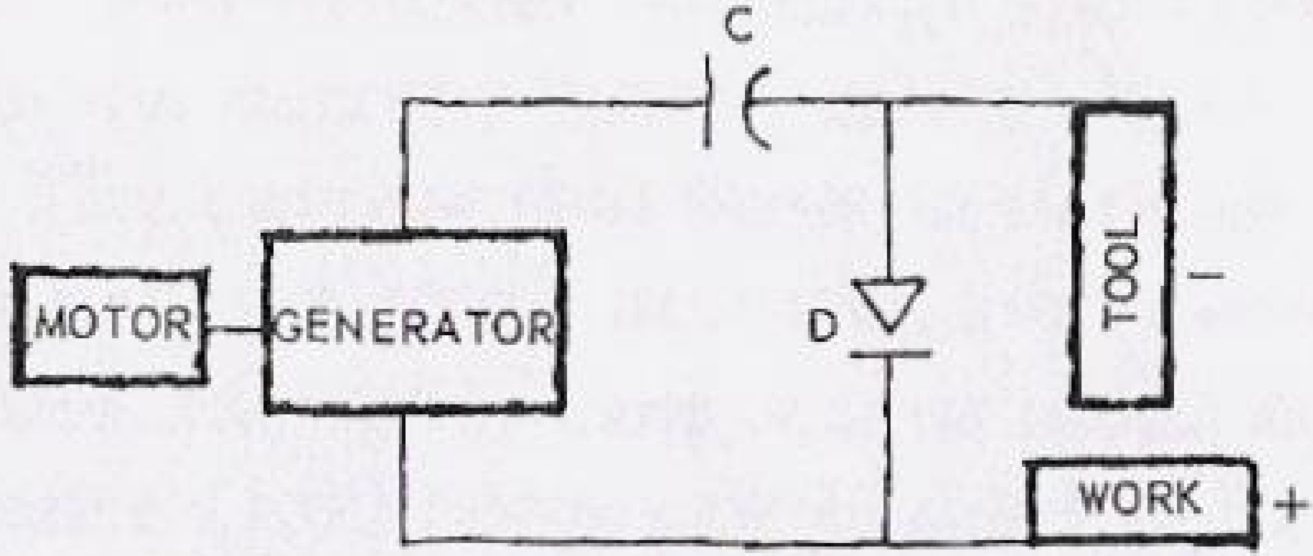
Types:

- Several basic types of electrical circuits are available to provide pulsating DC to EDM machines
- No one particular type is suitable for all machining conditions

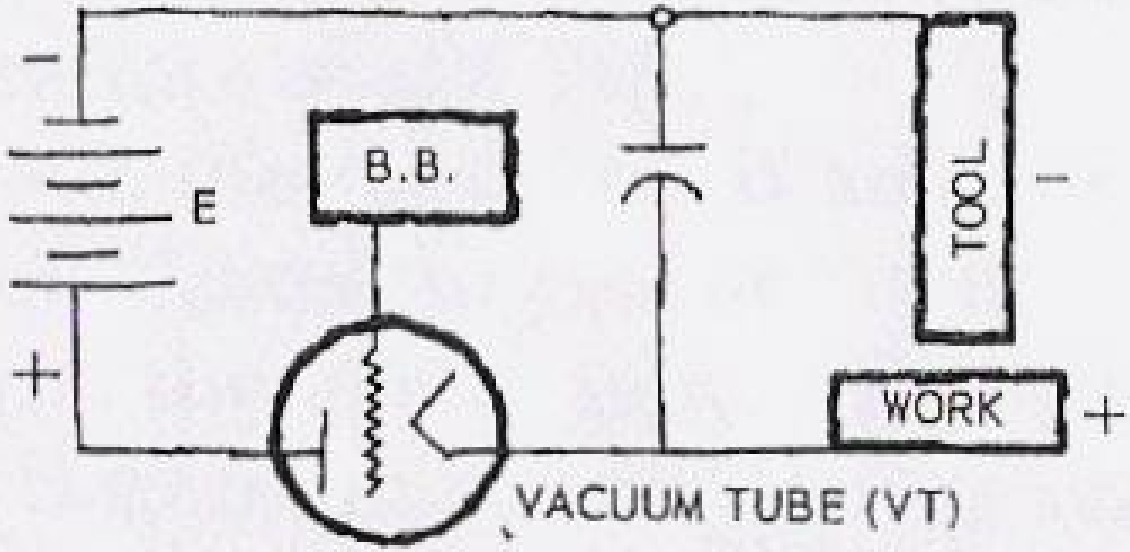


A BASIC CIRCUIT

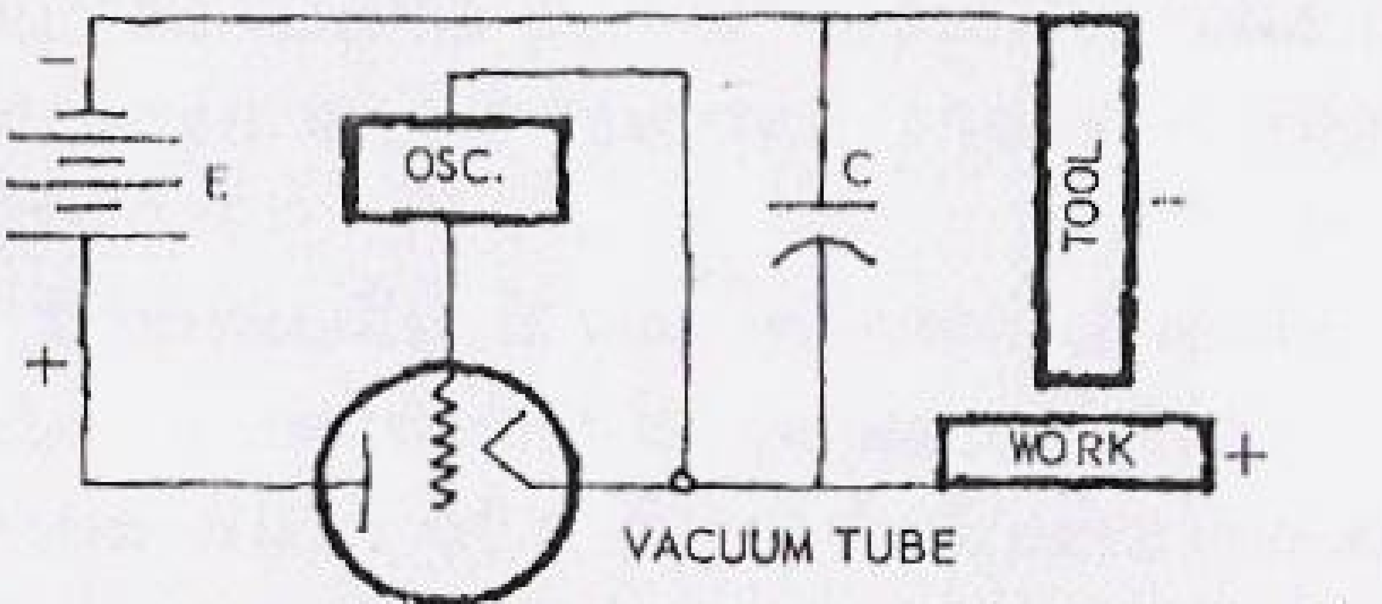

R
E
C
TOOL
WORK
B
R–C CIRCUIT



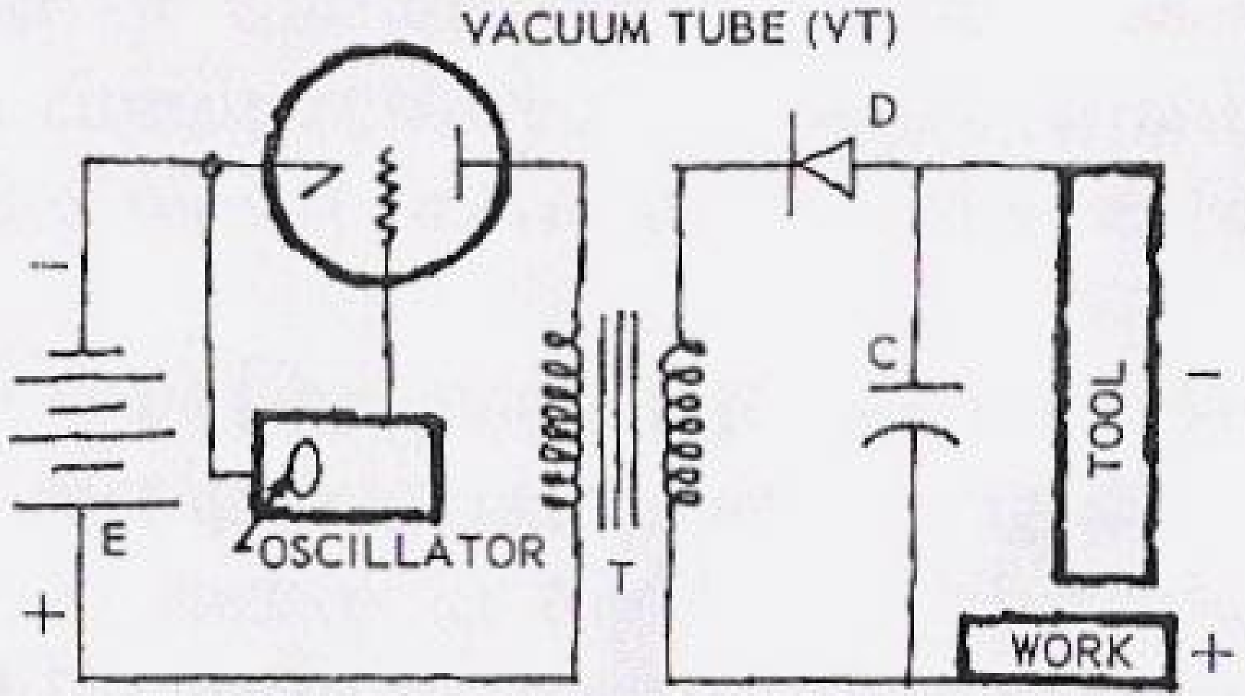
C ROTARY IMPULSE GENERATOR



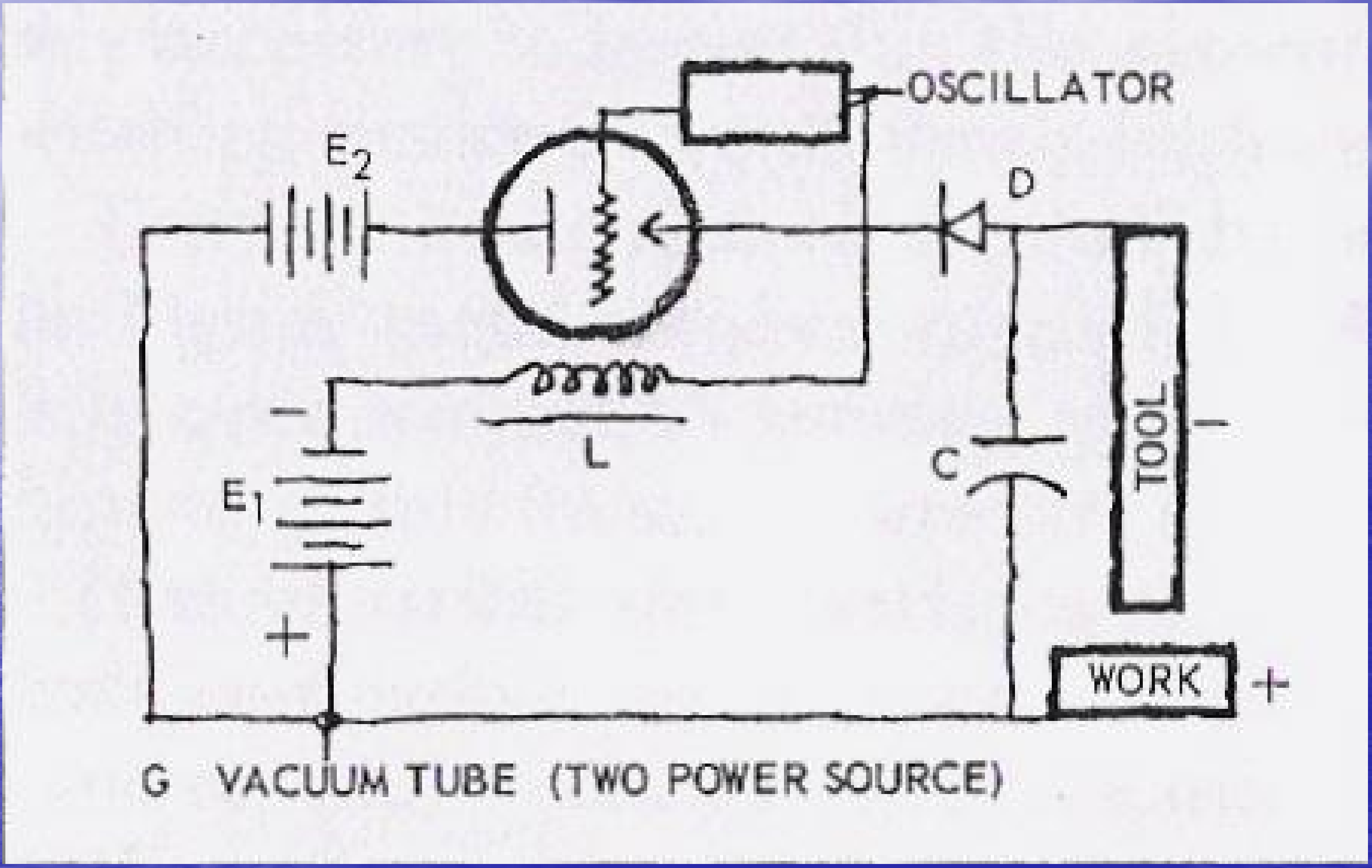
D CONTROLLED PULSE (VACUUM TUBE)

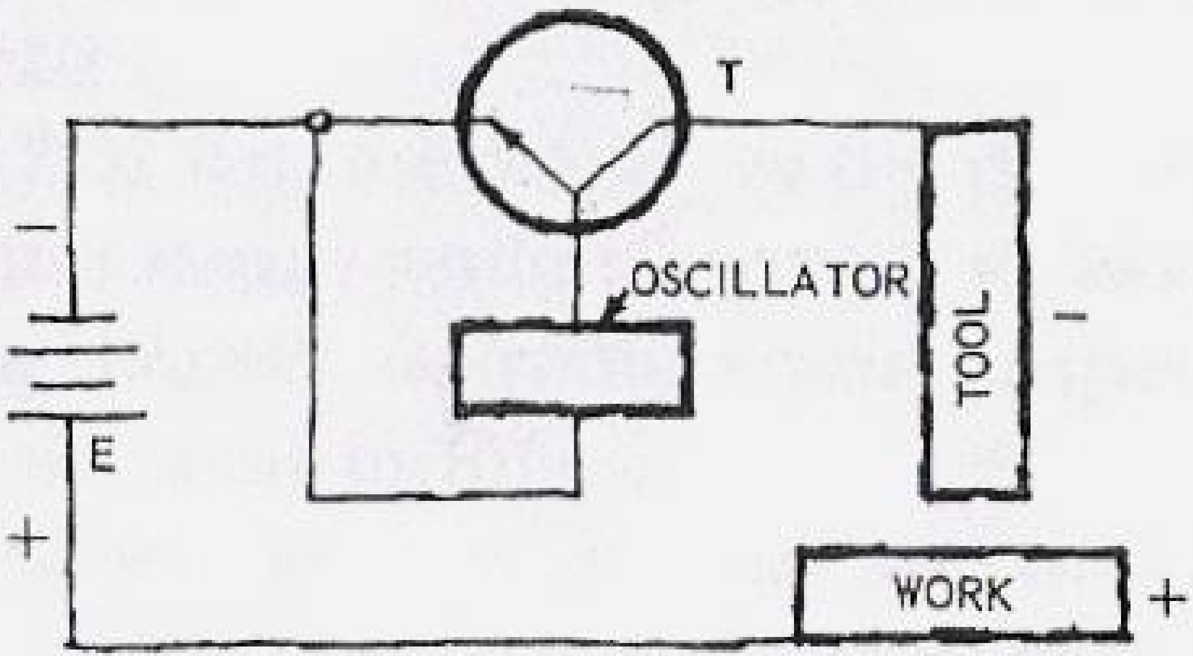


E OSCILLATOR CONTROLLED PULSE (VACUUM TUBE)



F VACUUM TUBE AND TRANSFORMER CIRCUIT


OSCILLATOR
E2
D
L
E1
C
TOOL
WORK
G VACUUM TUBE (TWO POWER SOURCE)



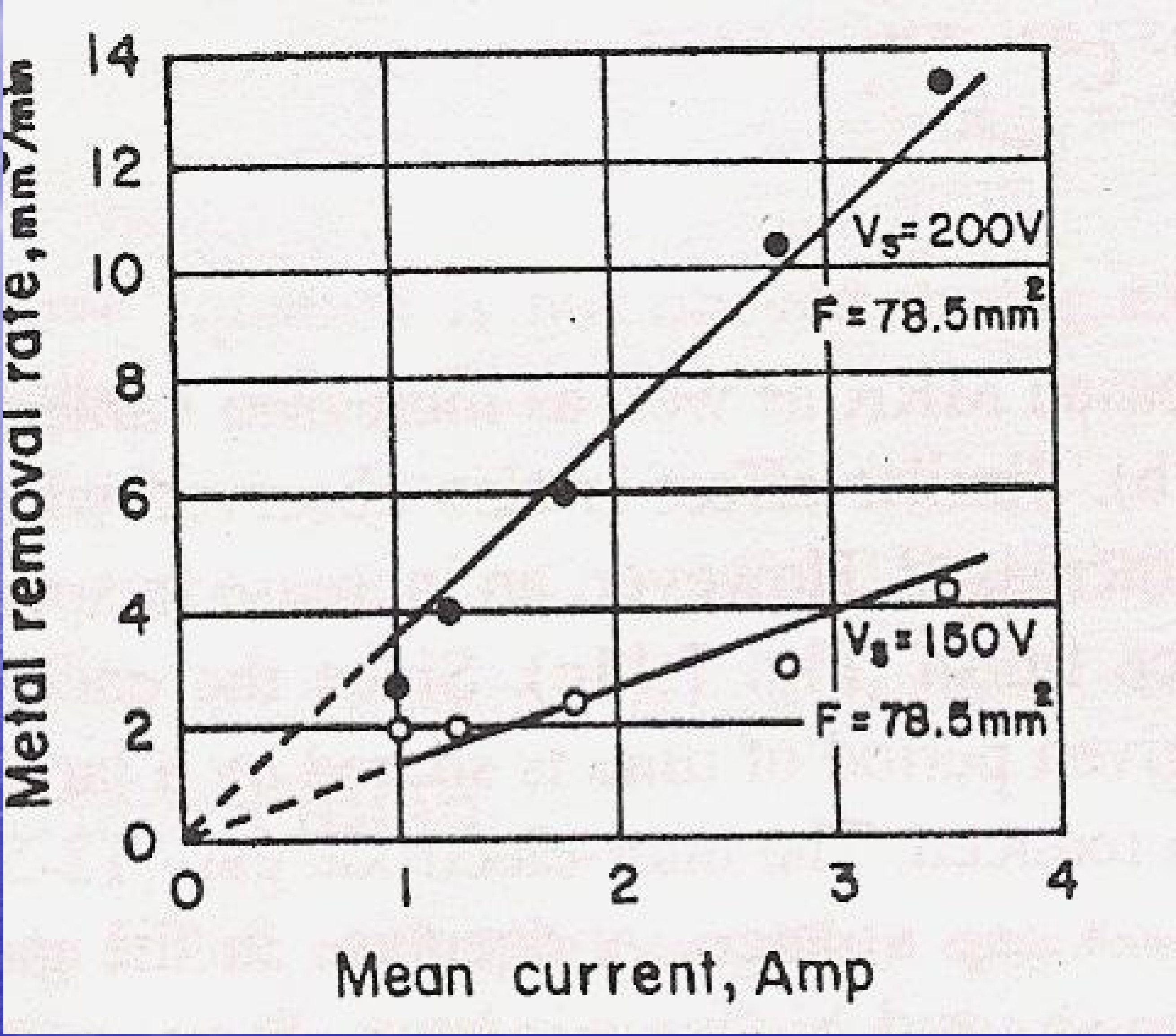
H TRANSISTOR PULSED CIRCUIT

Table V-3. Advantages and Disadvantages of Various Power Supply Circuits

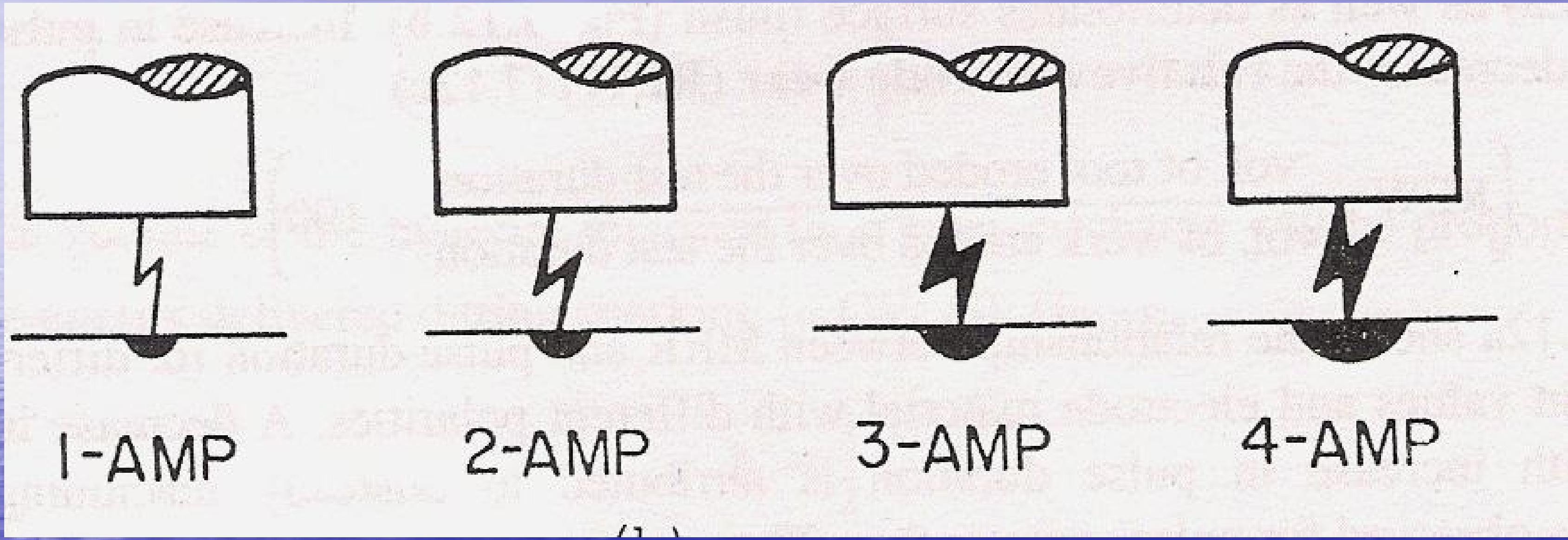
Type	*Advantages*	*Disadvantages*
Basic	Simple, low cost	Low frequency, rough surface at higher metal removal rates (MRR)
Resistance-Capitance (RC)	Simple, rugged, reliable, higher frequencies, low cost	Relatively low machining rates for smooth surfaces
Rotary impulse generator (RIG)	Capable of high metal removal rates	Rough surfaces
Controlled pulse-vacuum tube	High frequency controls eliminate short circuit, good metal removal rates, improved electrode wear	Characteristics of vacuum tube and gap not compatible: Arc gap = high current = low voltage Vacuum tube = high voltage = low current Must use auxiliary power source or transformer to compensate
Controlled pulse-transistor	(Same as vacuum tube) plus higher efficiency due to compatibility with arc gap.	

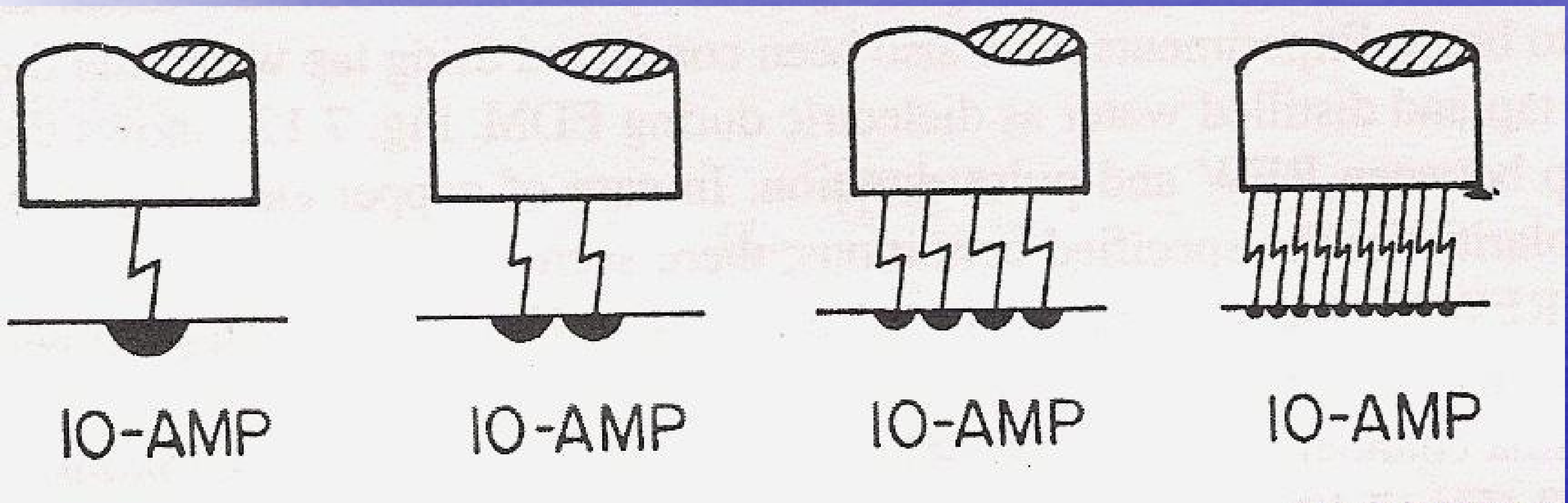
Process parameters

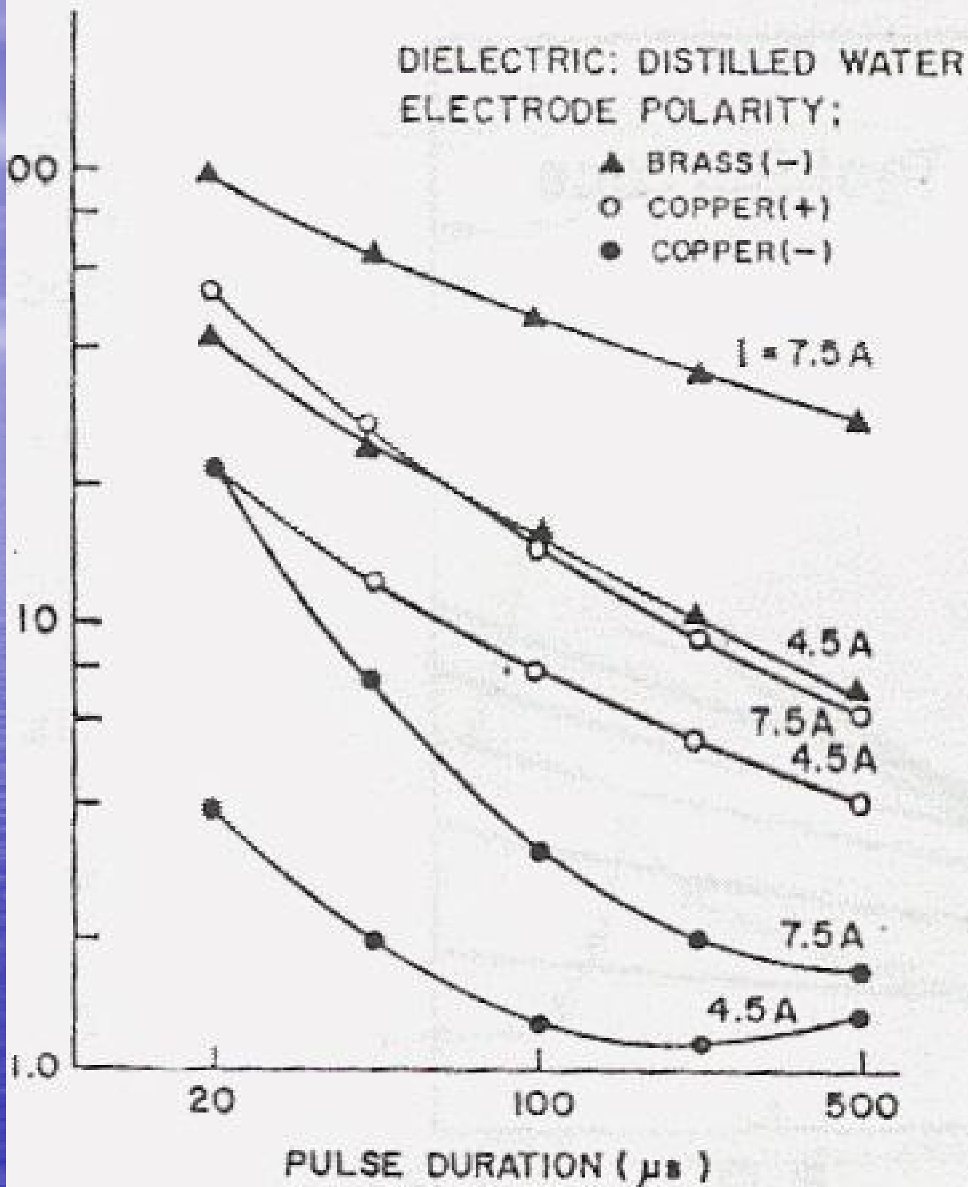
- Discharge energy
- Capacitance
- Dielectric fluid
- Deionization
- Frequency
- Overcut
- Material removal rate (MRR)
- Heat affected zone (HAZ)
- Electrode wear



Metal removal rate, mm³/min
14
12
10
8
6
4
2
0
0
1
2
3
4
Mean current, Amp
Vs = 200V
F = 78.5mm²
Vs = 150V
F = 78.5mm²

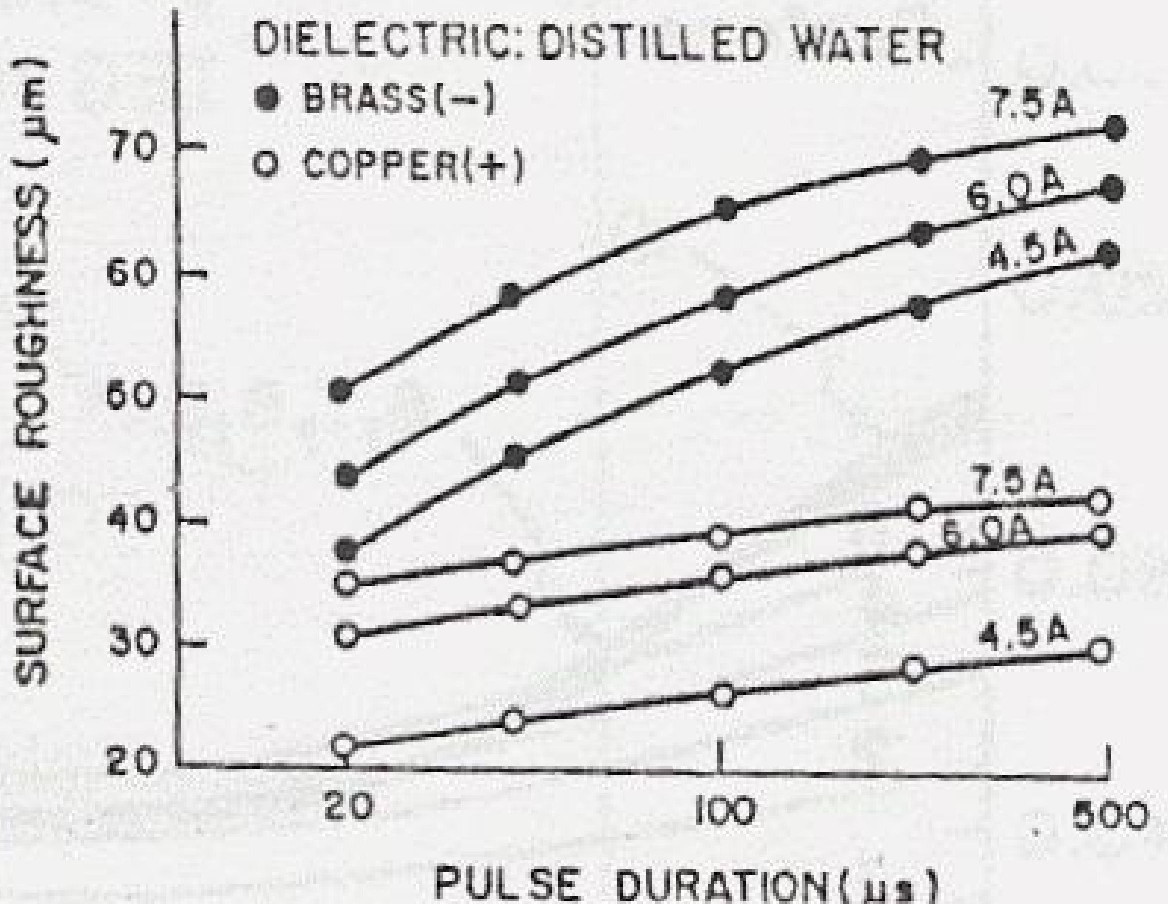

1-AMP
2-AMP
3-AMP
4-AMP


IO-AMP
IO-AMP
IO-AMP
IO-AMP

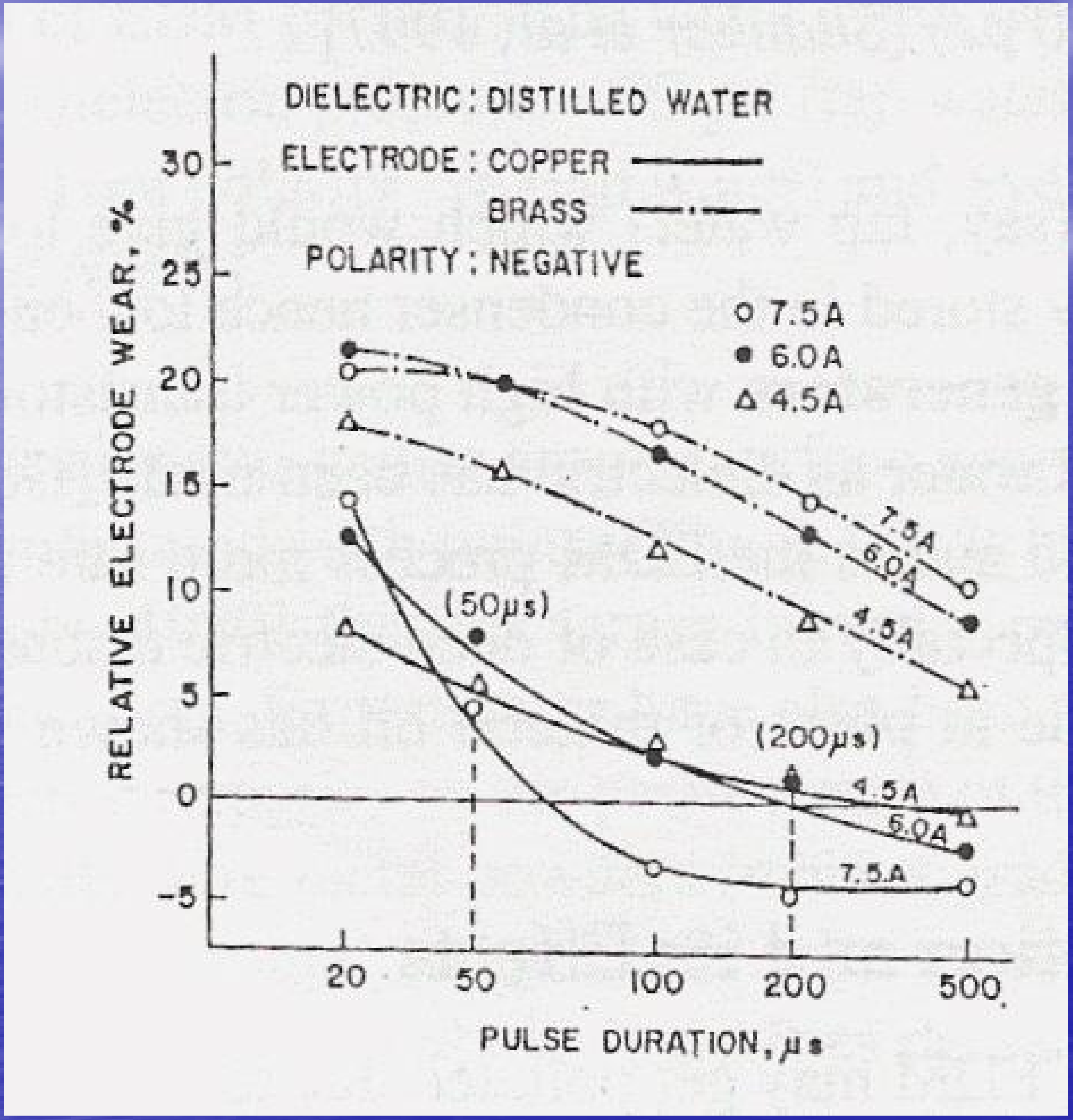


DIELECTRIC: DISTILLED WATER
ELECTRODE POLARITY;
BRASS(−)
COPPER(+)
COPPER(−)
I = 7.5 A
4.5 A
7.5 A
4.5 A
7.5 A
4.5 A
00
10
1.0
20
100
500
PULSE DURATION (μs)

(a)


DIELECTRIC: DISTILLED WATER
BRASS(−)
COPPER(+)
7.5A
6.0A
4.5A
7.5A
6.0A
4.5A
70
60
60
40
30
20
SURFACE ROUGHNESS (μm)
20
100
500
PULSE DURATION (μs)

(b)


DIELECTRIC : DISTILLED WATER
ELECTRODE : COPPER
BRASS
POLARITY : NEGATIVE
○ 7.5A
● 6.0A
△ 4.5A
RELATIVE ELECTRODE WEAR, %
30
25
20
15
10
5
0
-5
(50μs)
(200μs)
7.5A
6.0A
4.5A
4.5A
6.0A
7.5A
20
50
100
200
500
PULSE DURATION, μs

Advantages

- Can be employed to machine any material (hard, tough, brittle, exotic etc.,) provided it has some minimum electrical conductivity
- Matte finish obtained during EDM minimizes polishing time required
- EDM enables choosing of better die materials without worrying about its machining problems
- Dies manufactured by EDM are free of burrs and have higher life as compared to dies made by conventional methods – it permits the use of more durable die materials such as carbide, hardened steel etc.,
- Can be used to produce shapes which are extremely difficult to make otherwise – squares, D holes, splines, narrow slots and grooves, blended features etc.,
- No mechanical force acts as in conventional machine. Hence the process can be employed to machine thin and fragile components without any damage due to such forces
- High aspect ratio
- High accuracy

Disadvantages

- Low material removal rates
- Electrodes consumable
- Limited to electrically conductive workpieces
- Produces recast layer and HAZ
- Complex electrodes can require long lead times for fabrication
- Lacks flexibility for quick changes in hole shapes

Applications

- EDM is by far the most widely used machining process among the non-conventional machining methods
- EDM has long been employed in the automotive, aerospace, mould, tool and die making industries
- It has also made a significant inroad in the medical, optical, dental and jewellery industries, and in automotive and aerospace R&D areas

Applications

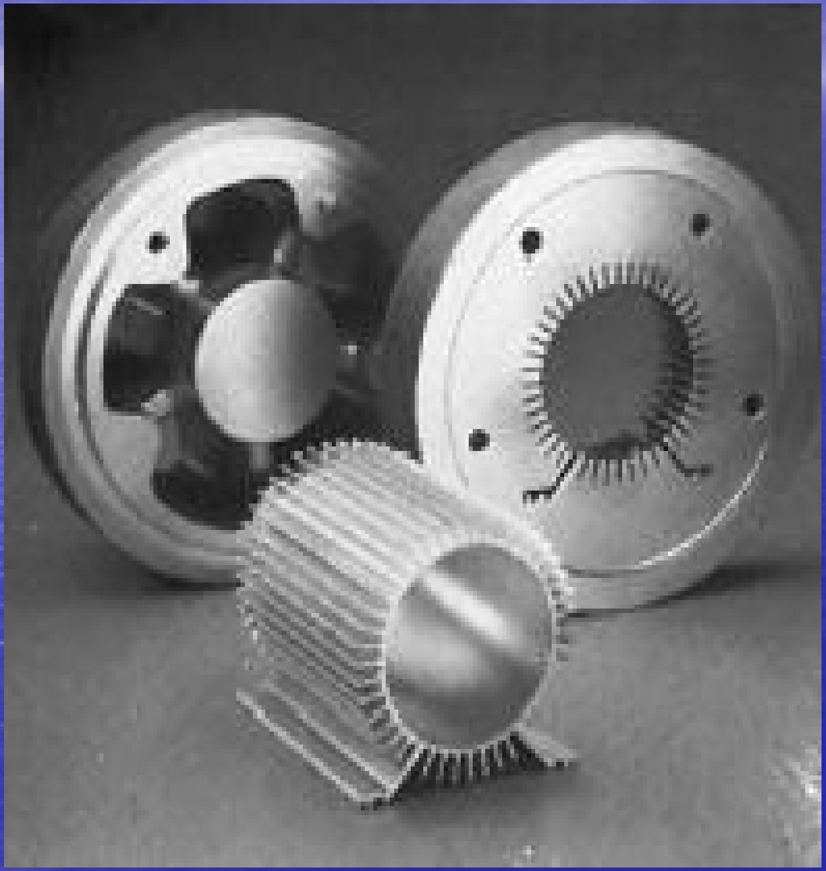
The process can be used economically for the following applications on workpieces, which are good conductors of electricity:

- For machining dies for moulding, casting, forging, coining, stamping, extruding, forging, header, wire drawing, blanking, etc.,
- For drilling fine deep holes (aspect ratio > 30) such as in fuel injector nozzles or drilling of fine deep holes through hardened ball bearing.
- For machining hydraulic valve spools
- For slitting of hard alloys
- For manufacture of fragile components which cannot be machined by conventional processes due to high tool forces
- For milling of heat treated materials such as tool steels – EDM allows tool steels to be treated to full hardness before machining, avoiding the problems of dimensional variability which are characteristic of post-treatment.
- For EDM of advanced ceramics
- For machining of metal matrix composites (MMC) and particle reinforced MMC (PRMMC)
- Micro-EDM – capable of not only micro-holes and micro shafts as small as 5μm in diameter but also complex 3D micro cavities.
- Removal of broken taps, drills, studs, reamers, pins etc.

APPLICATIONS

EDM

Examples of cavities produced by the electrical-discharge machining process, using shaped electrodes



Two round parts (rear) are the set of dies for extruding the aluminum the aluminum piece shown in front

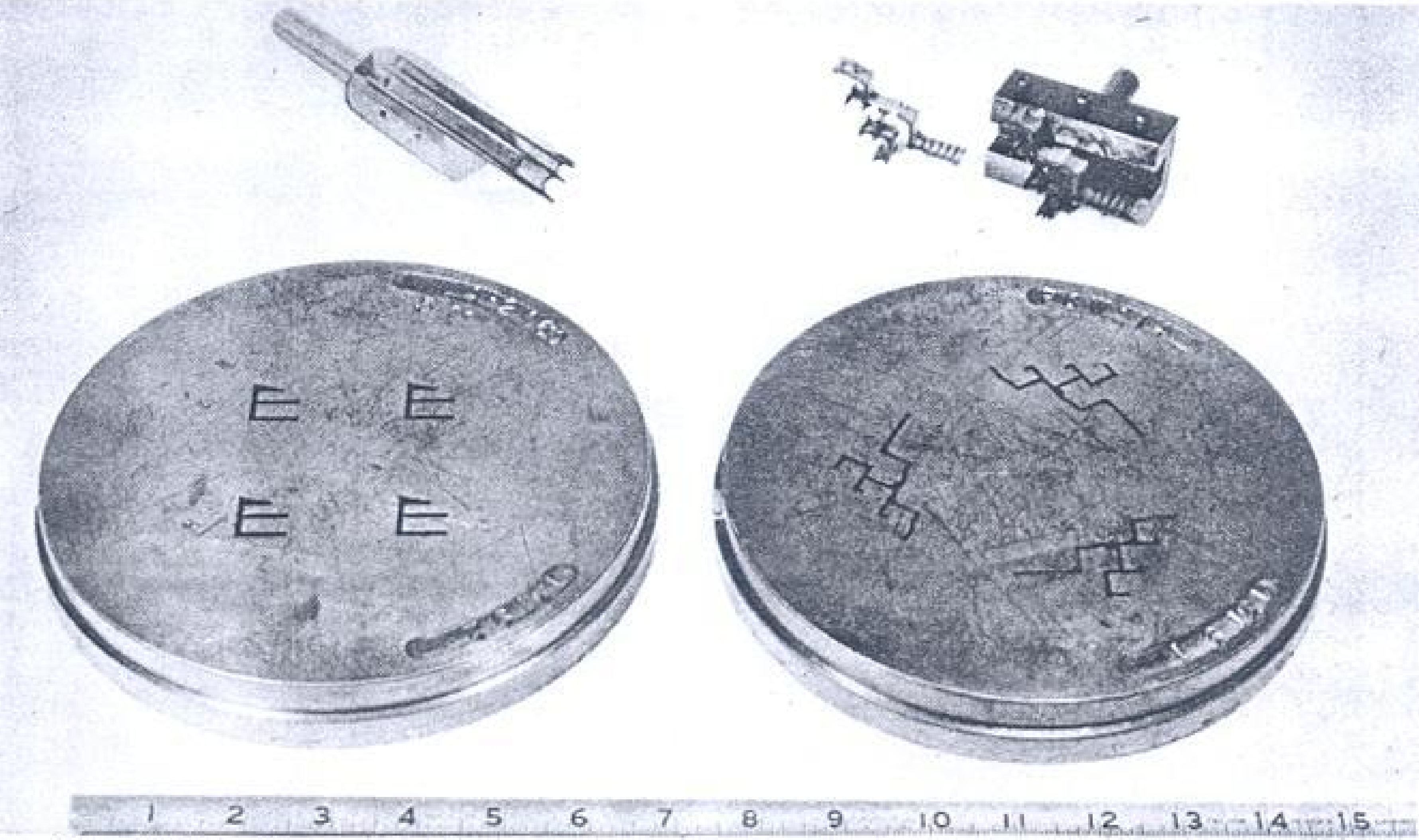


Fig. 5–25. Extrusion dies and electrodes. (*Courtesy, Elox Corporation of Michigan*)

Fig. 5–29. Forging die for jet engine impeller 12 in. in diameter, sunk by EDM from a solid block in approximately 24 hrs. A total of 88 cu. in. of metal was removed. *(Courtesy, The Ingersoll Milling Machine Company)*

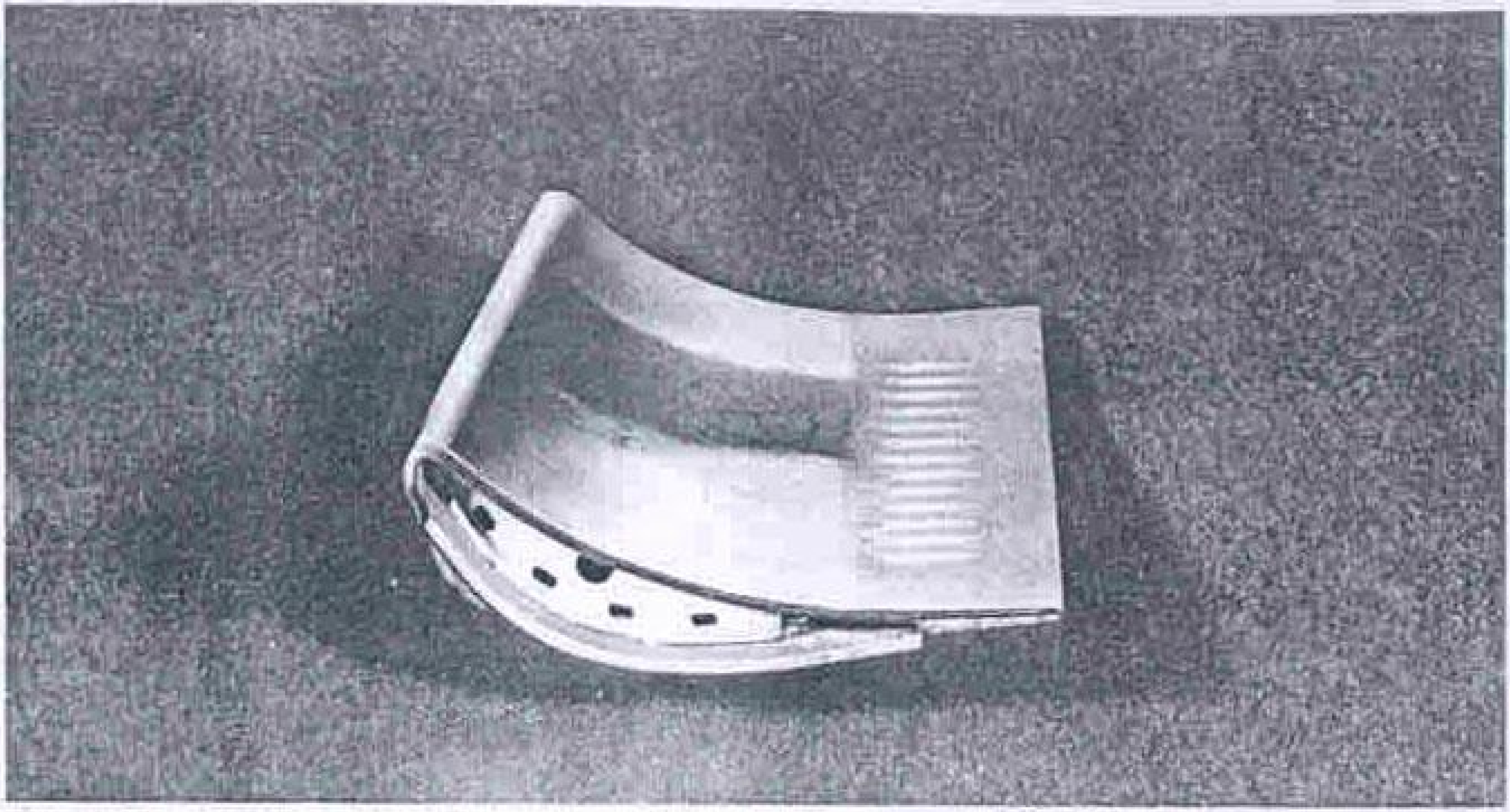


Fig. 5–30. Holes in trailing edge of jet engine vane drilled by EDM. *(Courtesy, Elox Corporation of Michigan)*

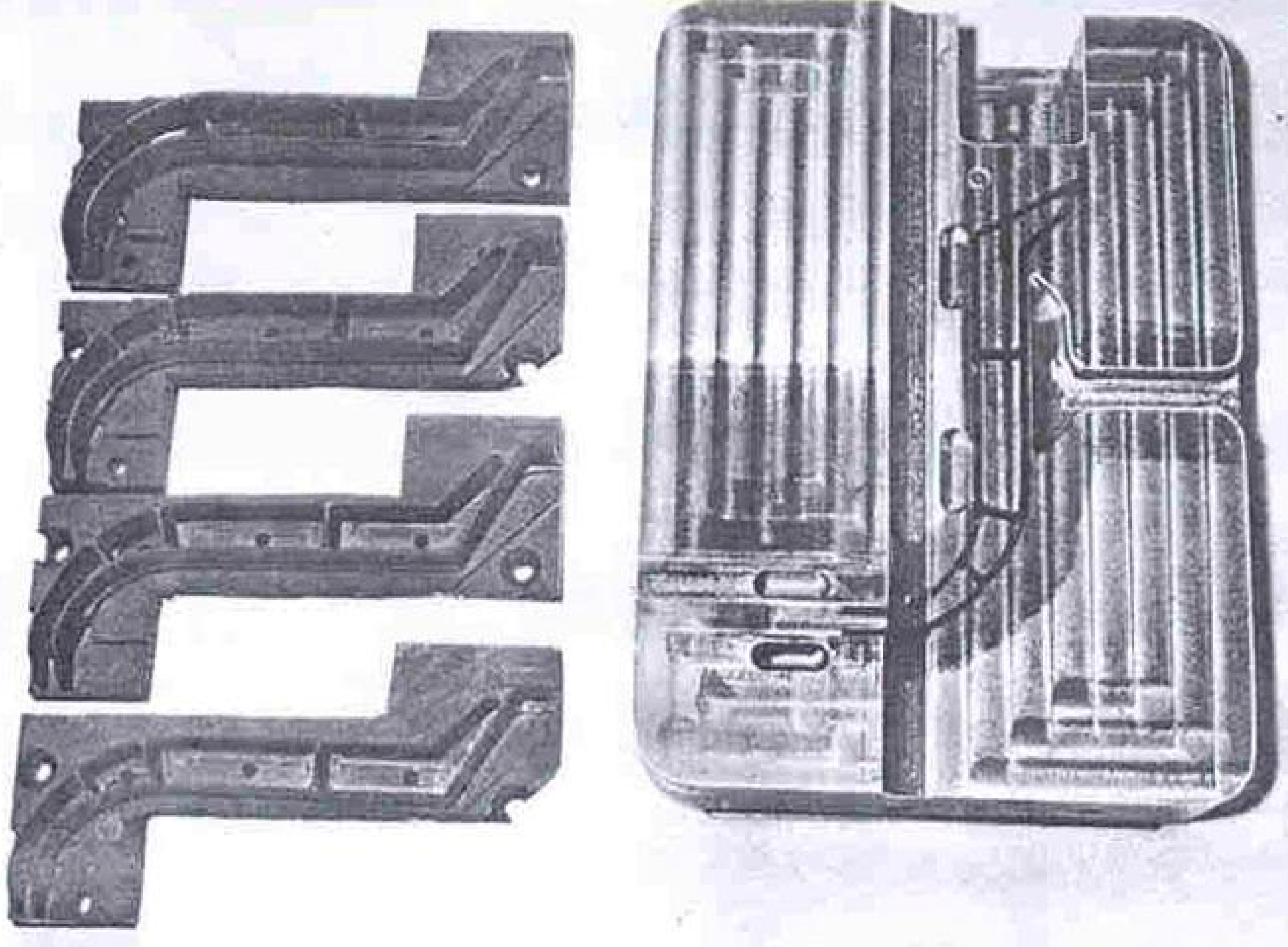


Fig. 5–28. Irregular rib slots in mold electro-discharge machined in approximately 3 hrs. *(Courtesy, The Ingersoll Milling Machine Company)*

Mold for an electric plug

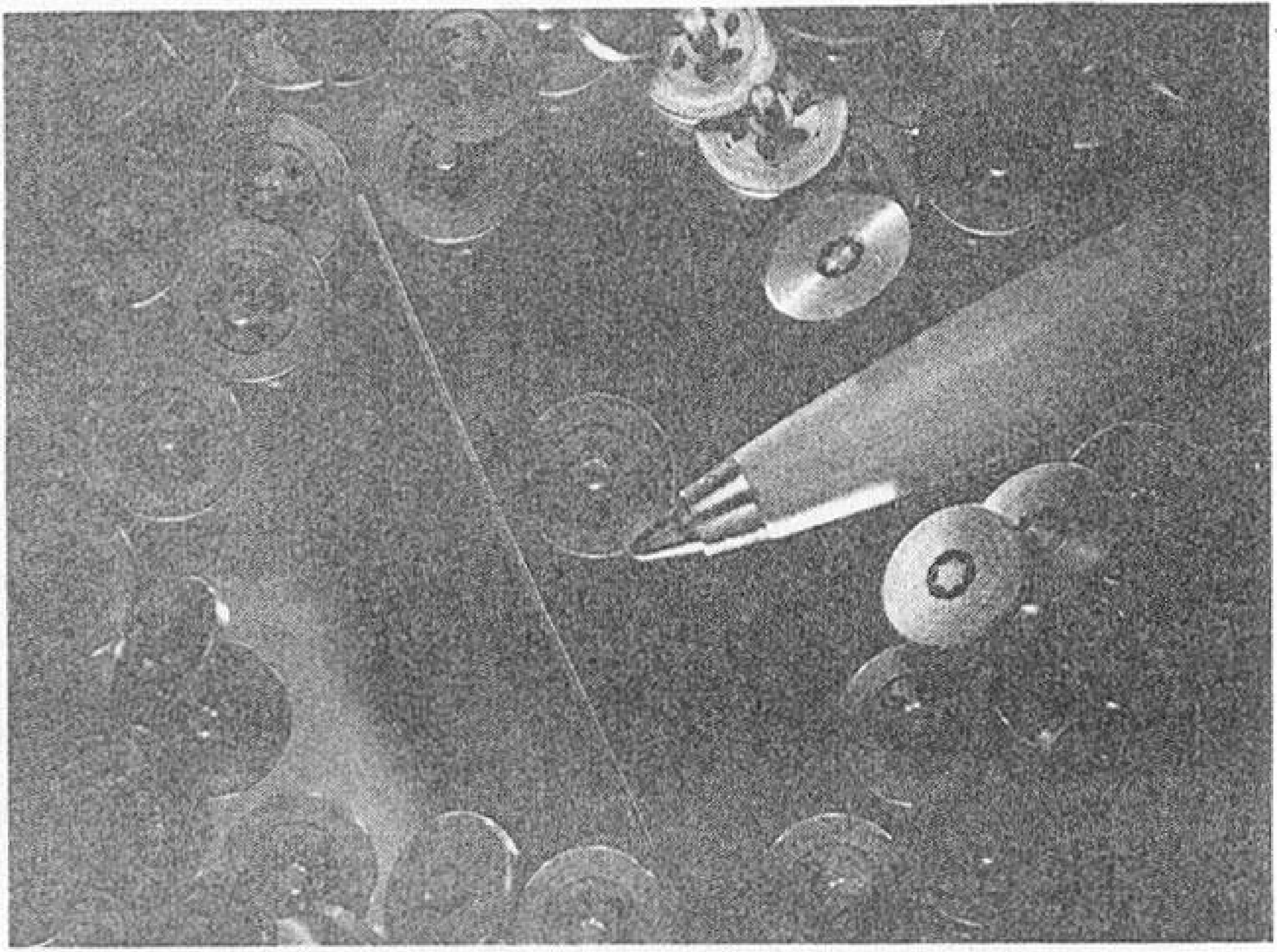


Figure 15.17 Small director nozzles used in automotive fuel injection systems are gang-drilled by EDM (*Source*: courtesy, General Motors Rochester Products Division, Rochester, NY).

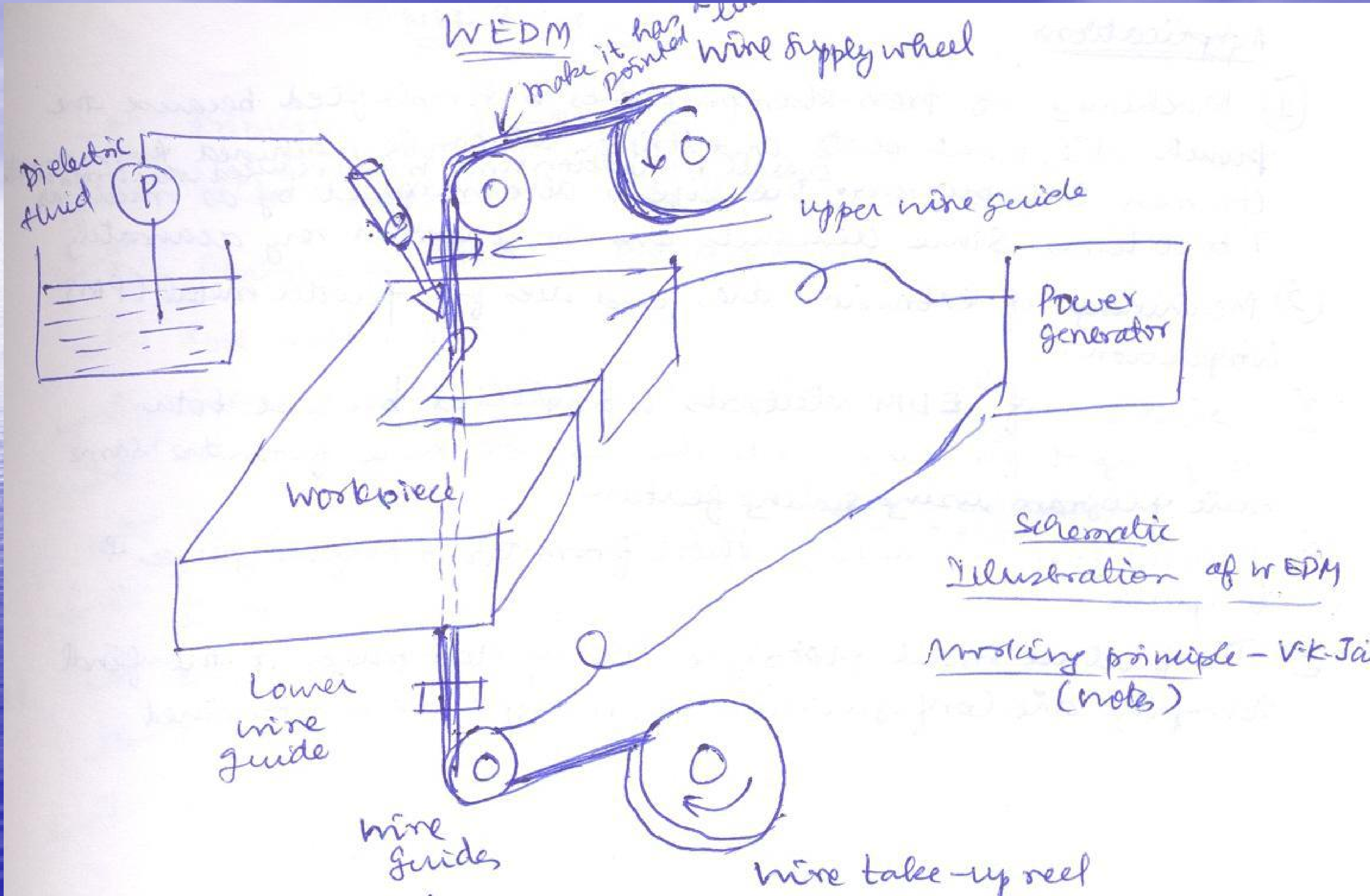
Fig. 5-26. Header dies and electrodes. *(Courtesy, Elox Corporation of Michigan)*

Fig. 5-27. Wire drawing dies. *(Courtesy, Elox Corporation of Michigan)*

WEDM - Introduction

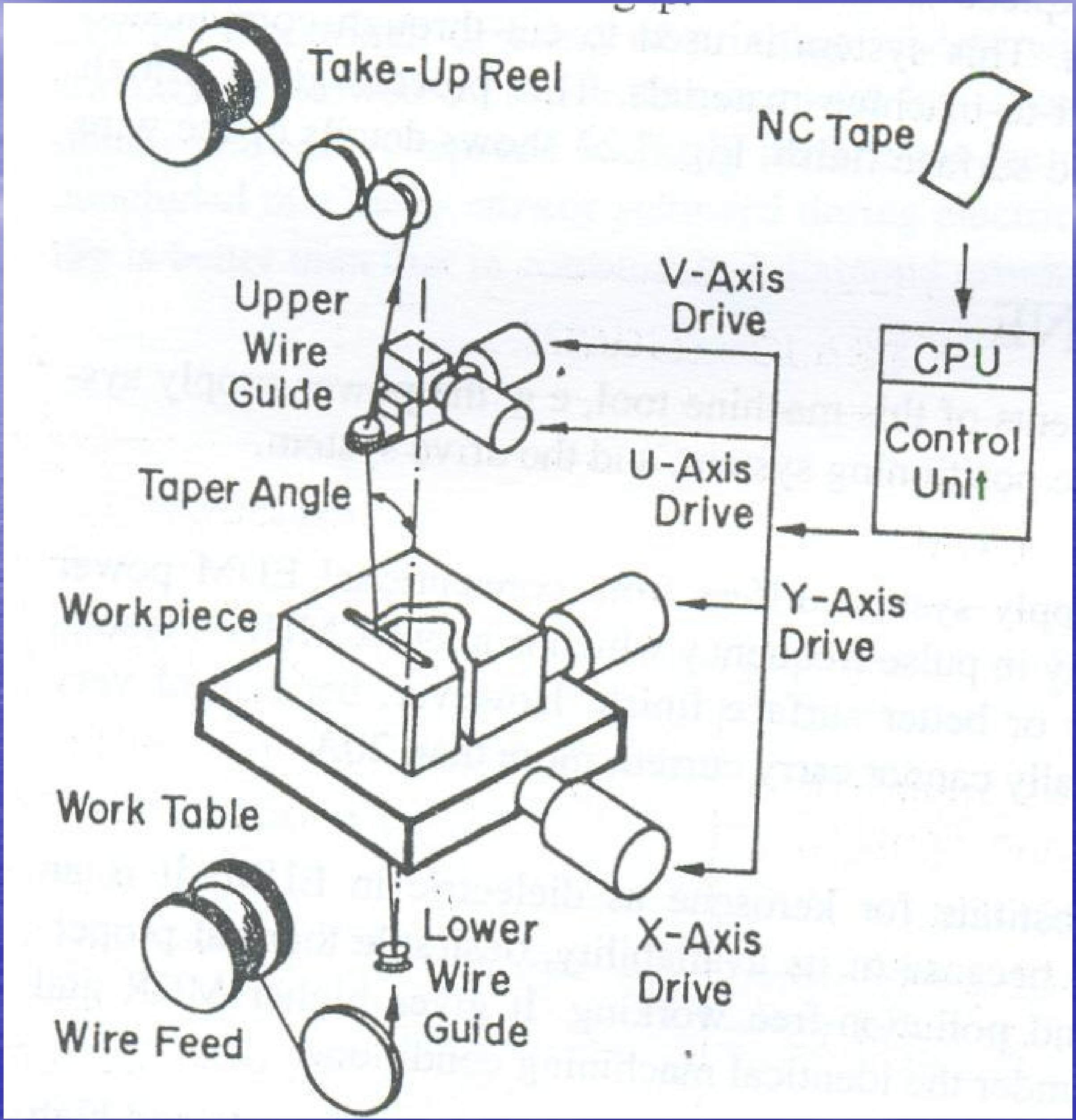
- Differs from conventional EDM in that a thin, 0.05-0.3mm dia wire performs as the electrode
- Unlike conventional EDM, the workpiece in WEDM is almost never submerged in dielectric fluid. Instead, a localized stream is used
- Advantage of using water as a dielectric – high MRR, no fire hazard – yielding for unattended machining

WEDM setup



WEDM
make it has pointed
wire supply wheel
Dielectric fluid
P
upper wire guide
Power generator
workpiece
Schematic Illustration of WEDM
Working principle – V.K. Jain (notes)
Lower wire guide
wire guides
wire take-up reel

WEDM setup



Take-Up Reel
NC Tape
V-Axis Drive
CPU
Control Unit
Upper Wire Guide
Taper Angle
U-Axis Drive
Workpiece
Y-Axis Drive
Work Table
Lower Wire Guide
X-Axis Drive
Wire Feed

Advantages

- No electrode fabrication required
- No cutting forces
- Unmanned machining possible
- Die costs reduced by 30-70%
- Cuts hardened materials

Disadvantages

- High capital cost
- Recast layer
- Electrolysis can occur in some materials
- Slow cutting rates
- Not applicable to very large workpieces

Applications

1. Machining of press-stamping dies is simplified because the punch, die, punch plate and stripper all can be machined from a common CNC program
   - overall fabrication time is reduced when compared to EDM
   - die life is also increased by as much as 7-10 times since clearances can be controlled very accurately
2. Machining of extrusion dies and dies for powder metal compaction
3. Fabrication of EDM electrodes is simplified because both roughing and finishing electrodes can be made from the same basic program using scaling feature
4. Fabrication of grinding wheel form tools, profile gauges and templates
5. To produce small prototype lots of stampings if the final stamping die configuration has not yet been determined

APPLICATIONS

WEDM

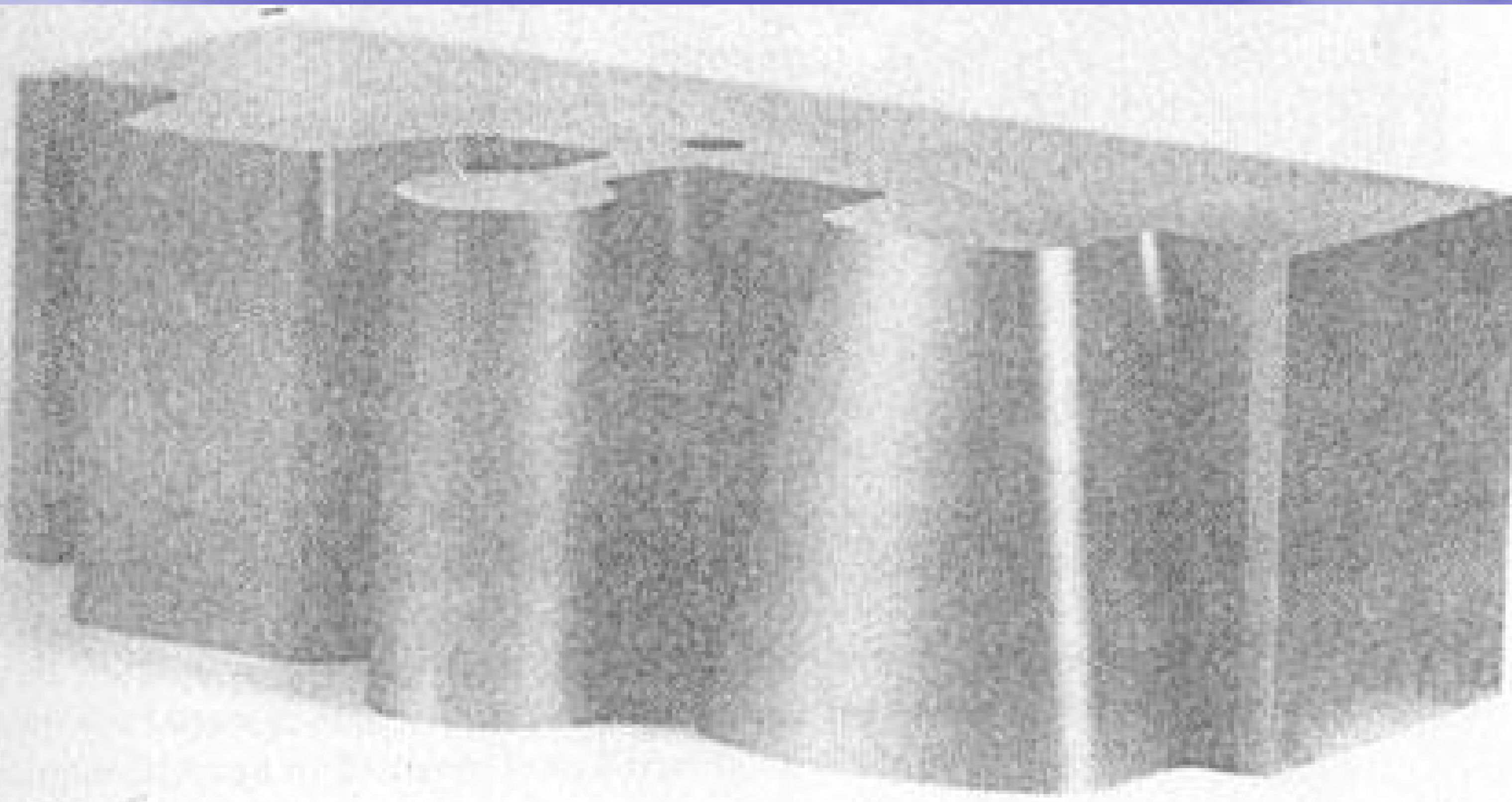


Figure 16.4 Example of the complex shapes that can be cut with wire-EDM and a taper-cutting mechanism (*Source*: courtesy, Colt Industries, Elox Division, Davidson, NC).

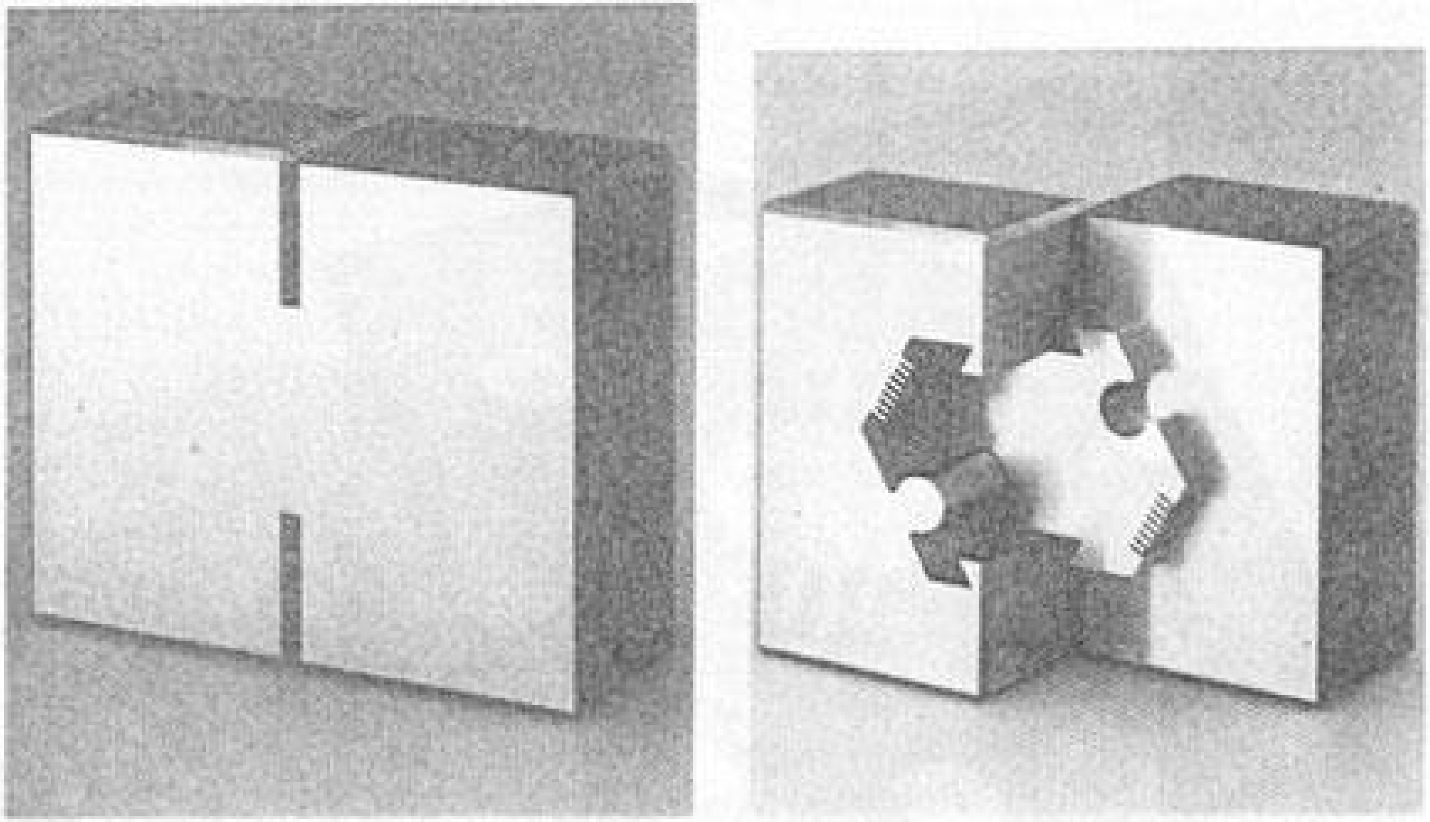


Figure 16.7 Example of the fit clearance that can be achieved with wire-EDM. The same workpiece is shown in both photographs. The fit clearance of 0.003 mm makes die parting lines invisible (*Source*: courtesy, Agietron Corporation, Addison, Ill.).

Prototype manufacture

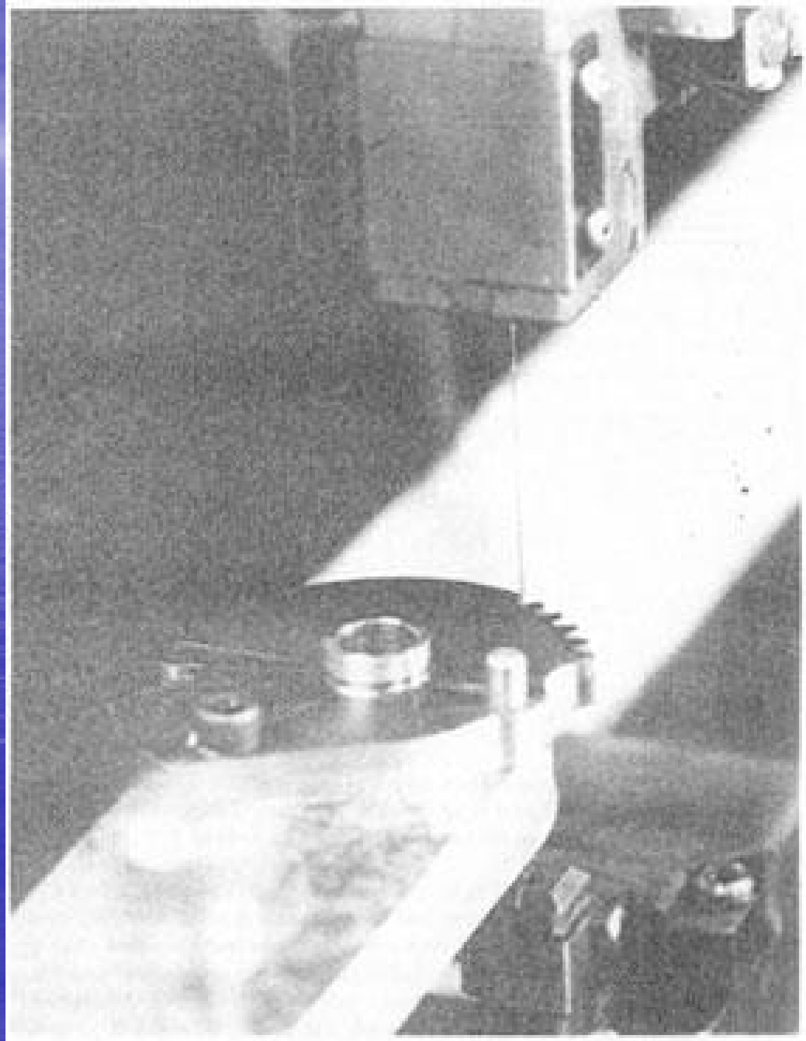


Figure 16.11 Wire-EDM being used to manufacture prototype sprocket (*Source*: courtesy, Japax/McWilliams Machinery Sales, Bridgeport Machines Division of Textron, Inc., Farmington Hills, Mich.).

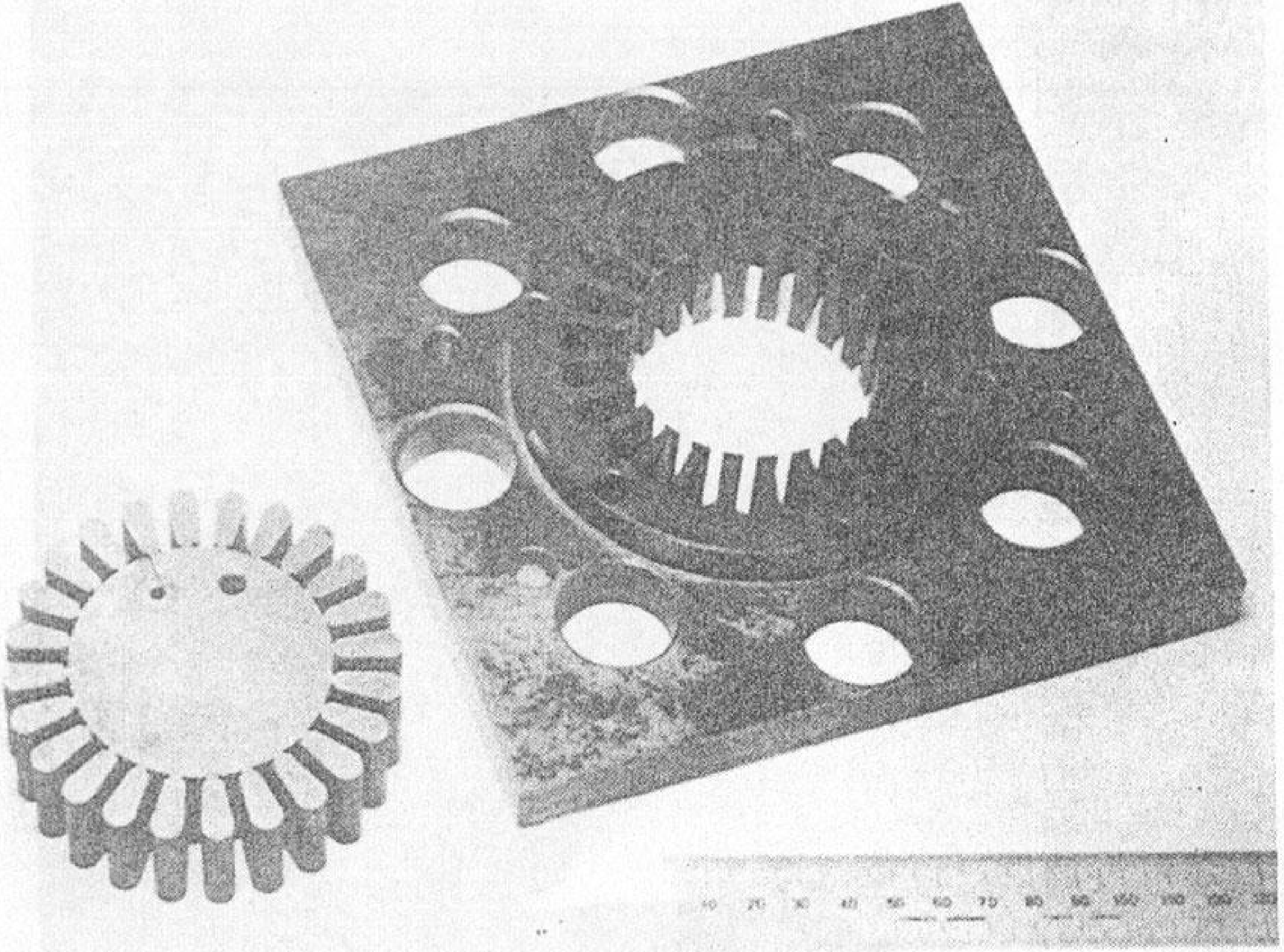
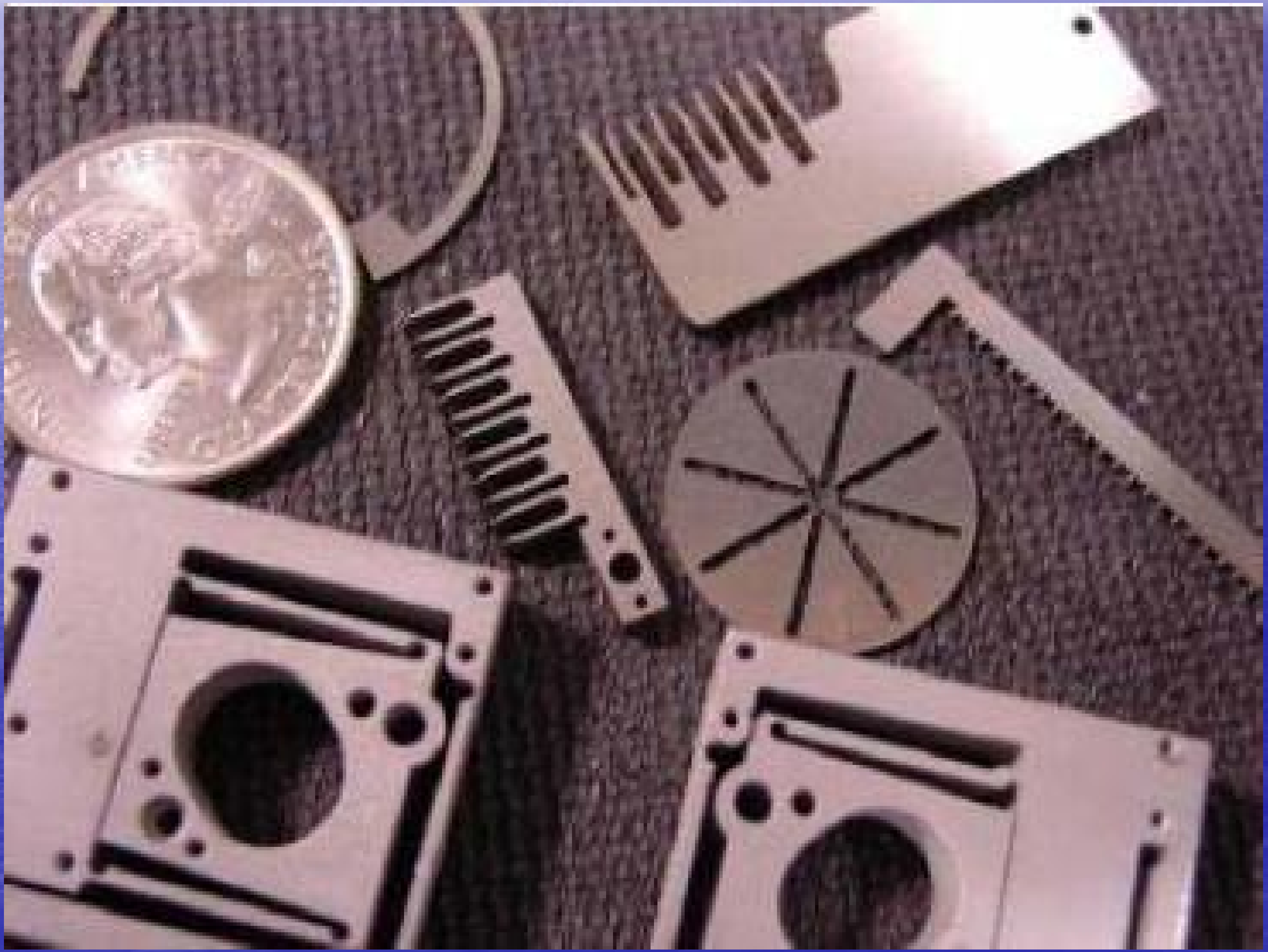


Figure 16.9 Stator core-stamping die machined by wire-EDM (*Source*: courtesy, Japax/McWilliams Machinery Sales, Bridgeport Machines Division of Textron, Inc., Farmington Hills, Mich.).

WEDM parts

WEDM parts



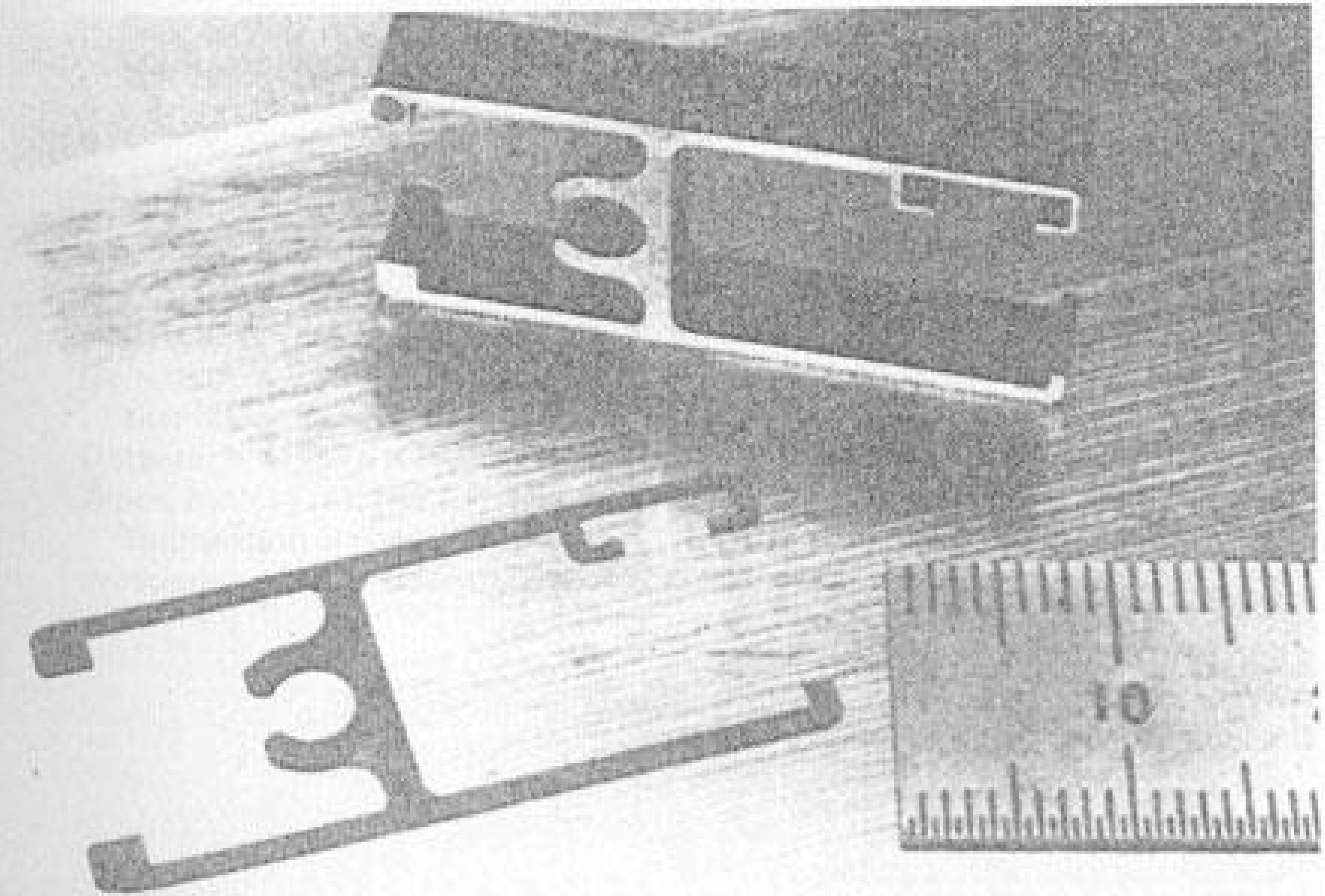


Figure 16.10 Aluminum extrusion die. Five-millimeter thick hardened steel shape is cut in 2.7 hr by wire-EDM. Surface finish is 5-8 μ (*Source*: courtesy, Japax/McWilliams Machinery Sales, Bridgeport Machines Division of Textron, Inc., Farmington Hills, Mich.).

Recent advances / trends in EDM - 1

1. **No wear EDM**: work to electrode wear ratio of 100 or more
- At a given current, the wear per pulse is nearly the same, regardless of the length of on-time
- Settings: Positive electrode polarity, long on-times, and low peak current
2. **CNC vertical EDM**: provides additional capability in servocontrolled motion and erosion
- At least three controlled axes although machines with as many as six axes are available
- Ability to produce contoured surfaces with ball-nosed electrodes in a manner similar to that of a CNC mill
- Other advantages/capabilities:
- Location of electrodes with respect to some reference location
- Multiple cavities with the same spark parameters
- Electrode wear compensation using touchoffs on reference surfaces
- On machine inspection with probes held in electrode holder
- Fast retrieval of spark settings for a given work-electrode combination
- Storage and retrieval of electrode offset data
- Multiple coordinate systems for workpieces at different locations and orientations

Coordinates for the shape to the cut are entered on a keypad of the EDM (in this case a cutting tool as shown on the monitor). The actual cutting is done by an electric arc in the water-tight chamber on the left.

Recent advances / trends in EDM - 2

3. **New Electrode Materials**: materials without developing excessive wear rates or produce no signs of electrode erosion

- MMC ZrB2/Cu – erosion rates that are several times lower than copper or various graphites; less expensive to manufacture and provides higher metal removal rates

4. **EDM without a Dielectric fluid**: functions of the liquid can also be achieved with a gas

- A clean gas is as good an insulator as a dirty EDM oil
- A high-speed gas flow can remove molten metal from the workpiece surface and immediately remove ions produced by the discharge
- A clean, high-speed gas flow in the discharge gap can be achieved when a pressurized gas is introduced through an electrode

Recent advances / trends in EDM - 3

5. **EDM using a Dielectric with conductive powders:** this technique uses an EDM fluid with suspended electroconductive powders that improves the quality of the workpiece surface in the finishing stages of EDM
6. **EDM of Non-conductive Materials**: Assisting electrode method – the surface of the insulating material such as ceramic etc., is covered in advance with a conductive material such as TiN through the PVD process

- Natural Si3N4 cannot be machined by EDM, but a metal-plated Si3N4 can be machined by EDM, though the thickness of the plated layer is negligibly small compared to the actual machining depth. An advantage with the new technology is the fact that no special change of the EDM machine is necessary