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ABSTRACT

The manual is for use by students learning electrical discharge machining (EDM). It consists of eight units divided into several lessons, each designed to meet one of the stated objectives for the unit. The units deal with: introduction to and advantages of EDM, the EDM process, basic components of EDM, reaction between forming tool and workpiece, operating procedures, setup methods, flushing methods, and machining parameters. Each lesson contains: (1) a statement of the objective, (2) detailed, illustrated information on one aspect of EDM, (3) vocabulary words (56 total, defined in the manual), and (4) a written theoretical or a practical assignment to check comprehension. An achievement test consisting of several questions is included for each unit. The manual also contains a three-item bibliography. (MS)

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Department of Education
Division of Vocational Education

ELECTRICAL DISCHARGE MACHINING

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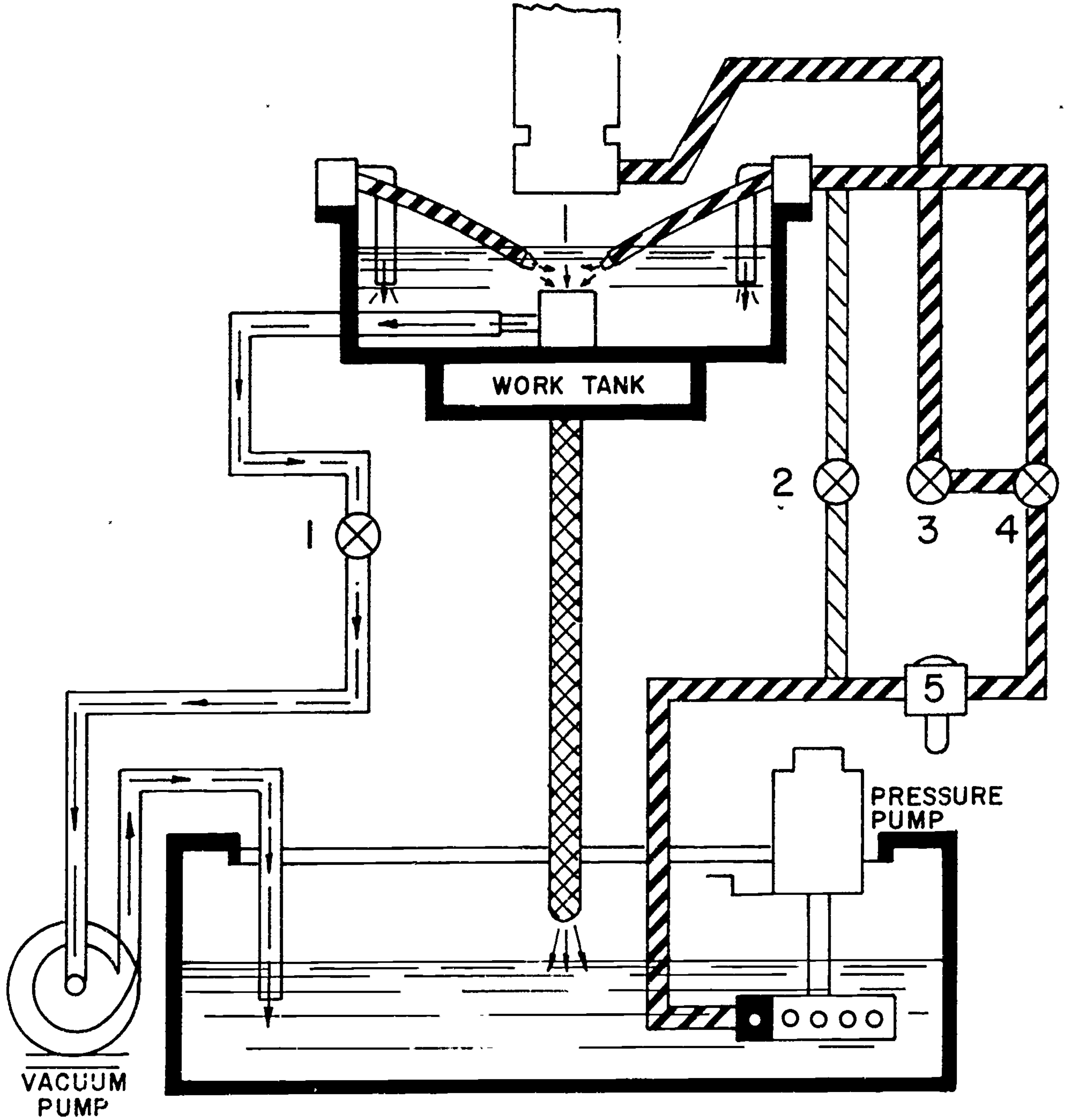
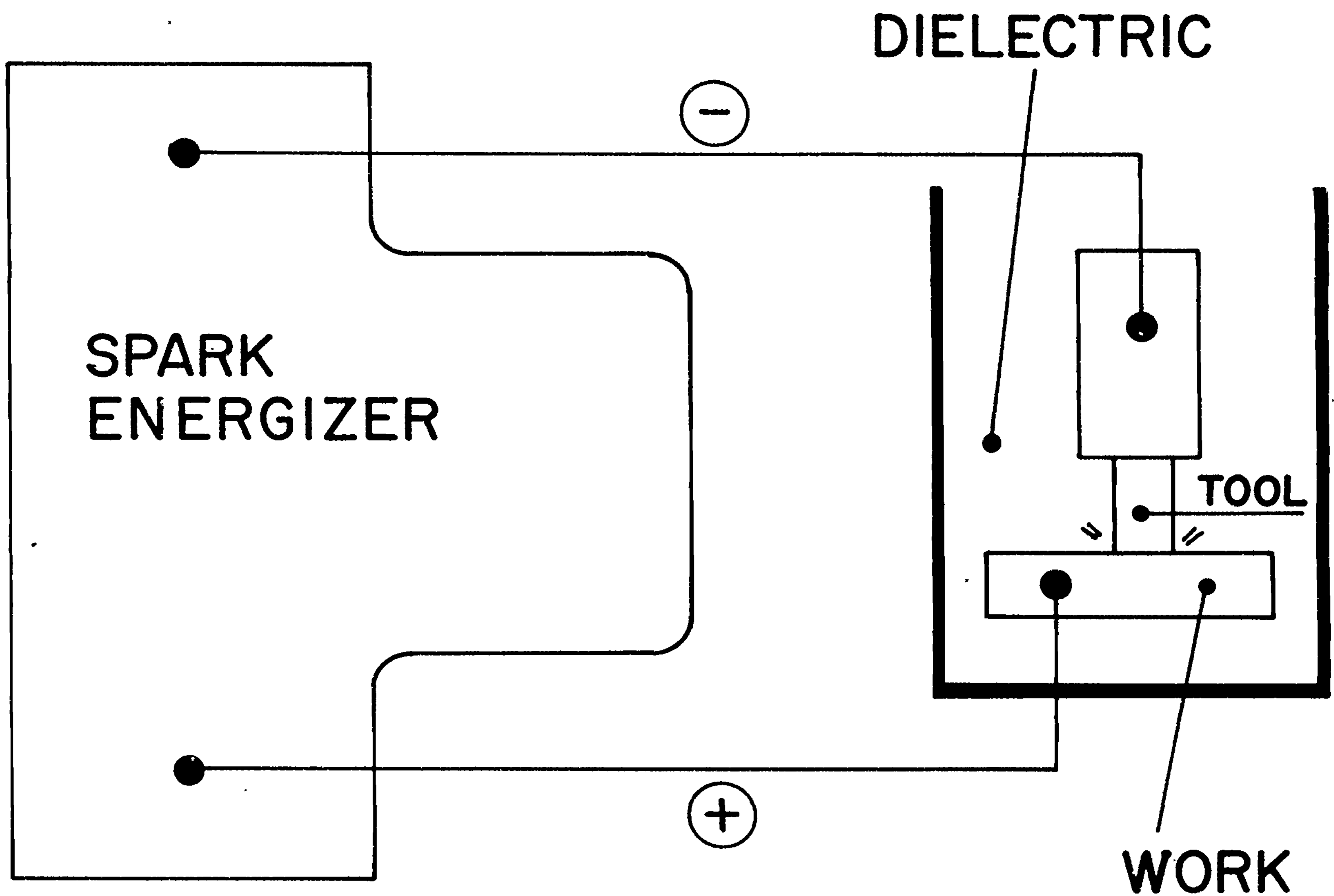
6. To relate metal removal rates to surface finishes
7. To relate descriptive finish terms to measurable finishes (microinch)



⊗ 1 FLUSH VACUUM
⊗ 2 FAST FILL
⊗ 3 CENTER FLUSH
⊗ 4 FILL PUMP
5 FILTER

PRESSURE
VACUUM
DRAIN
FAST FILL
⊗ VALVES

FLUID SYSTEM


DIELECTRIC
SPARK
ENERGIZER
TOOL
WORK

UNIT I

INTRODUCTION AND ADVANTAGES OF ELECTRICAL DISCHARGE MACHINING

Introduction — Lesson 1

OBJECTIVE:

To define Electrical Discharge Machining.

INFORMATION:

Electrical discharge machining is a metal-removal process in which workpiece material is removed by electrical erosion. The metal is eroded (removed) in exact amounts under controlled conditions.

EDM has finished its incubation period in the research laboratories and has moved into the production shops. A great increase in its use occurred in the immediate years prior to the first moon walk. EDM is the answer to many of the problems brought about by space-age requirements. Let it be clearly understood, however, that EDM is not a cure-all for all machining problems. It is a slow, time-consuming, specialized tool that serves very well in those situations where other metal-removal methods are not possible.

VOCABULARY:

1. EDM
2. incubation
3. erosion
4. specialized

ASSIGNMENT:

1. Define EDM.
2. Is EDM a new process?
3. Is EDM a speedy process?
4. Do you think the EDM machines will ever displace other metal-removing methods?

UNIT I

INTRODUCTION AND ADVANTAGES OF ELECTRICAL DISCHARGE MACHINING

Advantages of EDM — Lesson 2

OBJECTIVE:

To learn the advantages of EDM.

INFORMATION:

1. EDM can be used to machine any material, regardless of its hardness, brittleness, melting point, or fragility. The material must be a conductor of electricity.

2. EDM can be used to machine any shape as long as a tool can be produced to do the job.

3. In EDM, tool stresses are almost zero. As a result, the ability to machine fragile parts is greatly enhanced. In conventional machining, the tool literally tears excess metal from a workpiece. As a result, great stresses are built up between the tool and the workpiece. In EDM, only electrical current is transmitted through the tool.

4. EDM is able to machine to close tolerances and produce burr-free edges.

5. EDM does not require constant operator attention.

6. EDM, to the die-maker, has the additional advantage of eliminating heat-treating after the workpiece is machined. The machining is done on a basic hardened material without fear of warpage or built-up stresses in the die.

VOCABULARY:

1. hardness	3. fragile
2. brittleness	4. warpage

ASSIGNMENT:

List the advantages of EDM.

ACHIEVEMENT TEST:

1. What materials cannot be machined by EDM?

2. You have a 1" thick piece of cold-rolled steel which requires a 1" through-hole. Would you do the job on a drill press or on an EDM machine?

3. You have a piece of 1/4" thick carbide requiring the same size hole. What machine would you use?

UNIT II

THE ELECTRICAL DISCHARGE MACHINING PROCESS

The Process — Lesson 1

OBJECTIVE:

To describe the physical reaction in the EDM process.

INFORMATION:

In the EDM process, a workpiece is immersed in a dielectric fluid. A tool electrode, machined into the desired shape, is lowered towards the workpiece. A voltage is applied between the tool and the workpiece. The normal polarity of this voltage is positive on the work and negative on the tool.

When the space between the tool and the workpiece becomes small enough (about 0.001), there is an electrical breakdown of the dielectric fluid between the tool and the workpiece. The electrical breakdown is followed by a spark discharge. A very high current flows in the spark for a very short duration, a millionth of a second. The instantaneous spark can have current values as high as thousands of amperes when the machine is adjusted to the coarse-finish setting.

The spark creates a gas bubble, caused by intense heat and high localized pressure, and causes a tiny eroded crater in the surface of the workpiece. At the same time, a tiny crater is eroded in the tool.

The particles which are eroded from the spark craters are dispersed in the fluid and flushed away from the machining region. Correct flushing is a prime requirement of EDM.

In EDM, the sparks occur thousands of times per second. Each spark removes or erodes a predetermined amount of material. Ordinarily, the spark occurs at the smallest distance between the tool and the workpiece.

As the tiny craters are produced, they overlap, and the shape of the tool electrode is exactly reproduced in reverse in the cavity or through-hole being eroded in the workpiece.

VOCABULARY:

1. dielectric
2. polarity
3. crater
4. predetermined
5. overlap
6. electrode

ASSIGNMENT:

Define each of the six vocabulary words.

ACHIEVEMENT TEST:

Describe the EDM process.

UNIT III

BASIC COMPONENTS

The Spark Energizer Lesson 1

OBJECTIVE:

To know the function of the spark energizer.

INFORMATION:

Like all metal-removal machines, the EDM is made up of several basic parts, each part having a distinct function to perform. We shall consider each in turn.

The spark energizer generates the sparks by which the workpiece is eroded. The sparks are generated by a group of magnetic shunts and a bank of discharge capacitors located in the head of the EDM.

The machining rate is controlled by the amount of energy developed in the shunts and capacitors. On an Acu-Ram this energy is controlled by the finish selector.

VOCABULARY:

1. spark energizer
2. magnetic shunt
3. capacitor
4. energy

ASSIGNMENT:

How is an EDM like other metal-removal machines?

The Servo-Mechanism | Lesson 2

OBJECTIVE:

To know the function of the servo-mechanism.

INFORMATION:

The servo-mechanism is the means of control by which the proper machining gap (0.001 inches) is maintained during the machining process. It consists of two parts: the amplifier and the motor.

The servo-drive motor is mounted in the head of the machine; the amplifier is in the column. The servo-amplifier senses the machining conditions at the contact end of the tool electrode and electronically directs the motor to advance or retract the tool as machining efficiency demands. The ability to retract gives an opportunity to break any shorts caused by dislodged machine particles caught between the sparking faces of the tool and the workpiece.

VOCABULARY:

1. servo-mechanism
2. retract
3. short

ASSIGNMENT:

What might cause the servo-mechanism to retract?

UNIT III

BASIC COMPONENTS

The Quill Assembly Lesson 3

OBJECTIVE:

To know the function of the quill assembly.

INFORMATION:

The quill of the EDM controls the vertical movement of the EDM tool electrode. The quill assembly includes an anti-backlash, precision gear reduction. The gear reduction is necessary for the servo-drive motor to adjust the tool to the very small and critical work-piece gap distance.

The quill assembly is also equipped with a rapid travel mechanism and a manual adjustment. By "jogging" the tool and careful use of the manual control, a set-up may be made in a minimum of time.

The quill assembly also includes a depth-stop feature to limit quill movement to predetermined limits.

VOCABULARY:

1. quill
2. anti-backlash
3. critical
4. "jogging"

ASSIGNMENT:

Discuss the necessity of anti-backlash precision gear reduction in the quill assembly.

The Worktable — Lesson 4

OBJECTIVE:

To know the function of the worktable.

INFORMATION:

No machine can be consistently accurate unless careful machining accuracy is built into the machine. This is true with the worktable. The table must be 90° to the movement of the quill longitudinally and transversely. The longitudinal and transverse movements of the worktable are controlled by handwheels. The handwheels are graduated into divisions of 0.001 inch. Gibs eliminate sideplay in the dovetail ways of the table. Locking devices are provided to prevent accidental movement of the table.

VOCABULARY:

1. longitudinal
2. dovetail
3. transverse
4. gib

ASSIGNMENT:

Why must the table of an EDM machine be 90° to the quill movement in two positions?

The Dielectric System Lesson 5

OBJECTIVE:

To know the functions of the dielectric system.

INFORMATION:

The fluid used in the EDM process is dielectric. It does not conduct electricity. The dielectric fluid serves several purposes:

1. It cools the machining area.

2. It sweeps away machined particles.

3. It resists the expansion of the gas bubble which results from each spark discharge. This resistance increases the pressure in the bubble and causes increased metal erosion per discharge.

The functions of the dielectric fluid system are twofold:

1. To fill and drain the work tank

2. To provide a direct fluid flow across the region of sparking.

ASSIGNMENT:

What advantage to the EDM process does increased pressure in the gas bubble provide?

ACHIEVEMENT TEST:

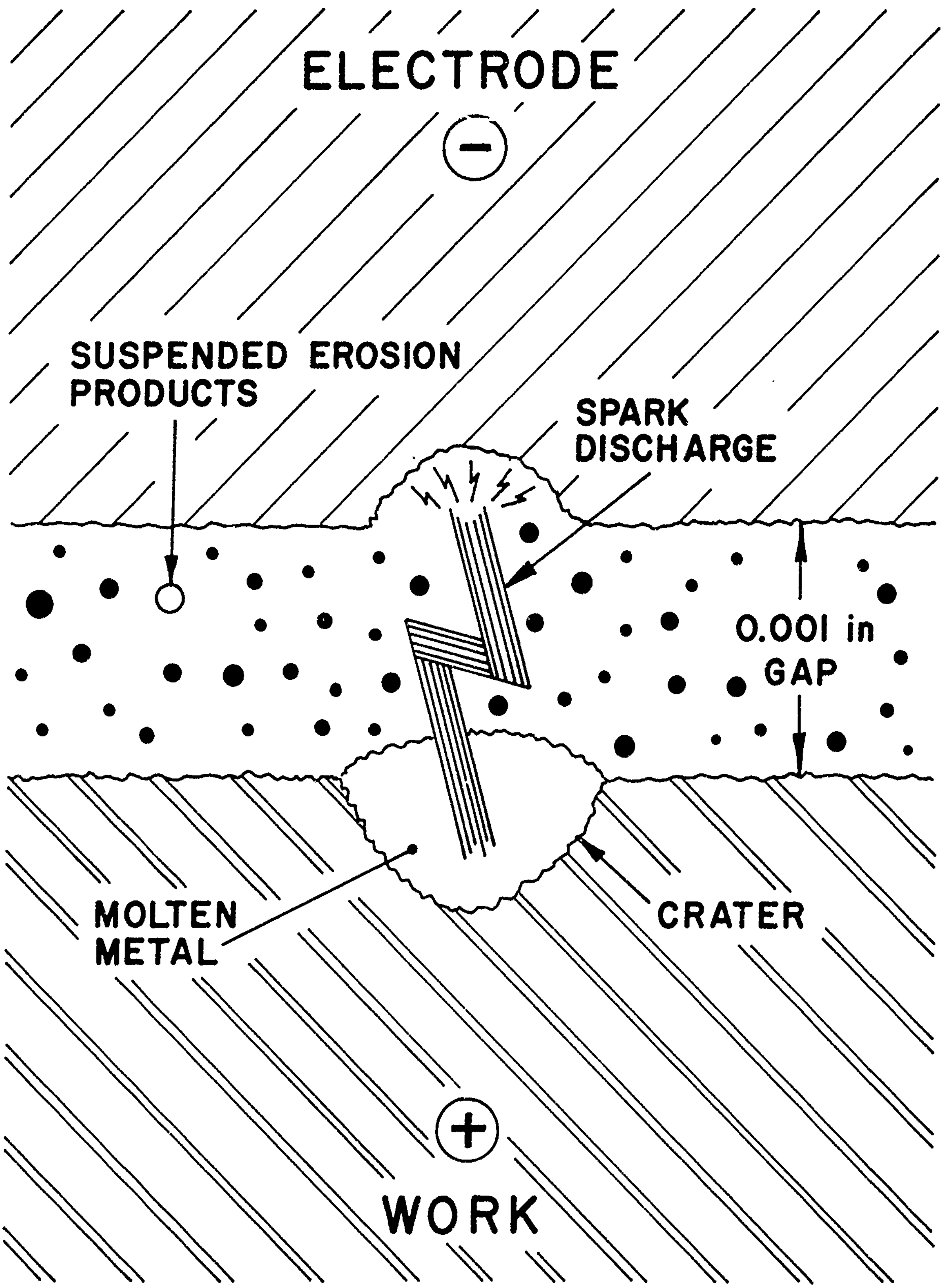
1. What is the function of the spark energizer?

2. What is the function of the servo-mechanism?

3. What movement of the tool electrode does the quill assembly provide?

4. What is the function of the worktable?

5. What is the function of the dielectric system?


ELECTRODE
SUSPENDED EROSION PRODUCTS
SPARK DISCHARGE
0.001 in GAP
MOLTEN METAL
CRATER
WORK

UNIT IV

REACTION BETWEEN THE FORMING TOOL ELECTRODE AND THE WORKPIECE

Electrode and Workpiece Reaction — Lesson 1

OBJECTIVE:

To illustrate by sketch the reaction between workpiece and electrode as the electrode approaches the workpiece.

INFORMATION:

(Refer to the illustration.) As the spacing between the parts becomes critical, an immense local electrical charge (as high as thousands of amperes) builds up at that point where the spacing is smallest. At the instant of discharge, the dielectric fluid breaks down. The fluid is changed to a gas, and a bubble is formed. Within that bubble, intense heat is generated, and a small particle of metal is melted from the workpiece. The flow of the dielectric fluid, containing the bubble, increases the pressure against the workpiece for that millionth of a second while the spark occurs. Then the fluid sweeps the eroded particle away. It clears the area for the next discharge.

As each discharge removes a tiny particle of metal, a crater is formed. A crater is a depression in the workpiece. Thousands upon thousands of discharges occur every second. Each spark causes a predetermined amount of erosion. From this fact, cutting rates may be derived.

VOCABULARY:

1. ampere
2. generated
3. crater
4. derived
5. debris

ASSIGNMENT:

1. What is the average sparking distance between the electrode and the workpiece?
2. Describe what happens in the gas bubble.
3. Where does the bubble come from?
4. How is the machining debris cleared away?
5. What is a crater?

ACHIEVEMENT TEST:

Draw a rough but legible sketch to illustrate the basic reactions in EDM.

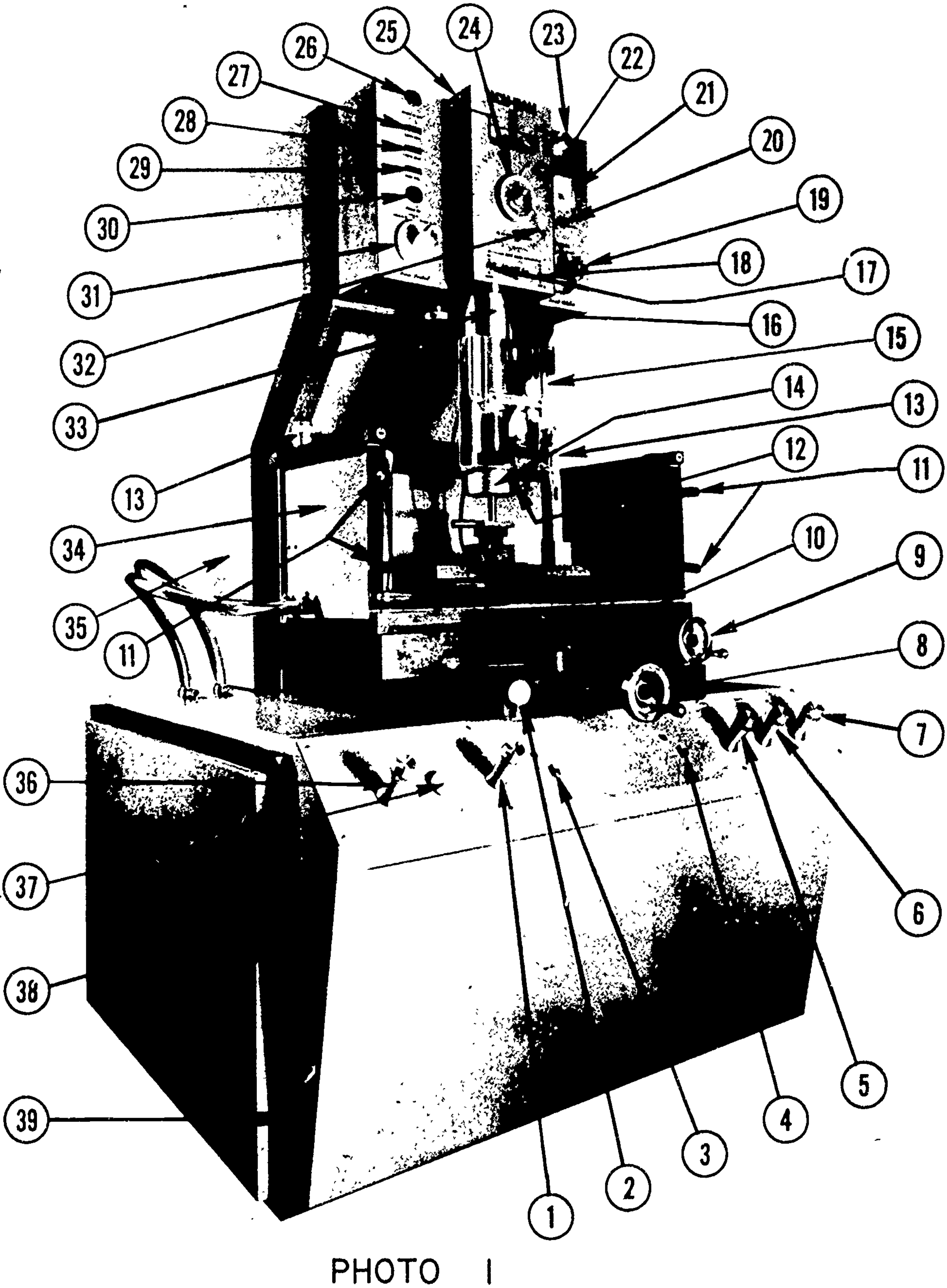

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PHOTO I

UNIT V

OPERATING PROCEDURES

Nomenclature   Lesson 1

OBJECTIVE:

To learn the names of the parts of an Acu-Ram EDM machine.

INFORMATION:

In this unit we will refer to the machine parts as illustrated on the opposite page. This is Photo 1 of an Acu-Ram, reprinted from the Acu-Ram operating manual.

KEY TO PHOTO 1:

1. Vacuum flush control valve
2. "Y" traversing locking clamp
3. Vacuum-pump control switch
4. Fill-pump control switch
5. Rapid-fill valve
6. Center flush control valve
7. Fill-pump control valve
8. "Y" traversing handwheel
9. "X" traversing handwheel
10. "X" traversing locking clamp
11. Swing-latch for work-tank front cover
12. Tool clamping screw
13. Work-tank drain valve
14. Quill
15. Protective guard
16. Quill drive selector
17. Rapid-travel UP-DOWN switch
18. Rapid-travel ON-OFF switch
19. Finish selector switch
20. Gap voltage adjust
21. Machining efficiency meter
22. Depth-stop indicator
23. Machining efficiency lamp
24. Depth-stop control
25. Machine head
26. Power-on-gap lamp
27. Depth-stop lamp
28. Servo-drive lamp
29. Fluid-level lamp
30. Auxiliary-power-on lamp
31. Power-control switch
32. Quill-travel indicator
33. Quill guide
34. Reservoir tank
35. Machine column
36. Reservoir-fill control valve
37. Cover for reservoir-fill hose
38. Left side access panel
39. Machine base

VOCABULARY:

nomenclature

ASSIGNMENT:

Locate and identify each part of the EDM machine illustrated.

The Work Tank | Lesson 2

OBJECTIVE:

To learn to fill and drain the work tank.

INFORMATION:

The work tank is that part of the machine which contains the worktable. It is liquid-tight and can be filled to a point deep enough to cover the workpiece.

To fill the work tank:

1. Close the work tank drain valves (13).
   These drain valves have overflows near the valve handles.

2. Close the center-flush control valve (6).

3. Open the fill-pump control valve (7).

4. Turn the fill-pump control switch (4) to "on" position.
   The dielectric fluid will now continuously recirculate.

To drain the work tank:

1. Turn off fill-pump control switch (4).

2. Open drain valves (13).
   The tank will drain by gravity in two minutes.

To drain the tank more rapidly and to clear all fluid from worktable:

1. Open the vacuum flush control valve (1).

2. Turn on the vacuum pump control switch (3).

ASSIGNMENT:

Fill and drain the work tank. Turn off all switches.

The Power Supply and Control Switches — Lesson 3

OBJECTIVE:

To learn the function of power supply and control switches.

INFORMATION:

The power-control switch (31) controls the electrical power to the auxiliary control circuits and the power to the spark energizer. When switch (31) is in "power off" position, all electrical circuits except the fill pump and vacuum pump are de-energized.

When power-control switch (31) is in "power on" position, the following circuits are energized:

1. Transistor power supplies.

2. The power supply for the servo-motor drive setup.

3. The 110-volt control circuits.

4. Accessory devices.

5. The fluorescent lamp and cooling fan.

When the power-control switch (31) is in the "power-on-gap" position, all the preceding circuits in addition to the following circuits are energized:

1. Servo-amplifier

2. The spark energizer (voltage is applied to machining gap).

VOCABULARY:

1. auxiliary
2. circuit
3. de-energized
4. function

ASSIGNMENT:

Turn the power-control switch to its different settings, and explain which circuits are energized and the function of each setting.

Machining Polarity Lesson 4

OBJECTIVE:

To learn of the flow of current in the EDM process.

INFORMATION:

The spark energizer supplies a direct, or one-direction, flow of current to the sparking area. Conventionally the current-flow is considered to go from the positive, or workpiece pole, to the negative, or electrode pole. In some materials the flow of current must be reversed to produce a good finish on the workpiece.

On the Acu-Ram, the machining current flows to the working area by means of the two large wires which run from the head (25) along the quill guide (33). One of these two wires is red, and the other is black. The red wire is the negative (-) lead, and the black wire is the positive (+) lead.

Normal polarity will be used for the majority of jobs in EDM. For normal polarity, connect the red wire (-) to the stud which extends from the rear of the quill, and connect the black wire (+) to the workpiece or worktank.

For reverse polarity machining, connect the black wire (+) to the stud, and connect the red wire (-) to the workpiece or worktank.

VOCABULARY:

1. negative 2. positive

ASSIGNMENT:

Discuss the flow of current in the EDM process.

UNIT V

OPERATING PROCEDURES

The Liquid Level Interlock — Lesson 5

OBJECTIVE:

To learn the function of the liquid-level interlock.

INFORMATION:

The work tank of the Acu-Ram is equipped with a float and micro-switch. They act as a safety interlock to prevent the application of voltage to the gap unless the work tank is full of fluid.

Also, if for any reason the liquid level should accidentally drop while the machine is operating while unattended, the interlock will automatically turn off the electric power to the gap, and the quill will withdraw to the "up" position. The interlock is mounted inside the back wall of the work tank.

VOCABULARY:

1. microswitch
2. interlock

ASSIGNMENT:

Locate the float, and manually operate the switch. All power must be switched to "off" on the machine.

Shank Size of Tool Electrode Lesson 6

OFJECTIVE:

To learn how to mount the tool in the quill head.

INFORMATION:

The shank of the tool electrode should be 5/8 inches square or round and 2 1/4 inches long. The depth of the tool holder is 2 inches. The center-flush hole through the tool electrode can be as large as 1/4 inch in diameter. The center flushing hole is sealed with an "O" ring around the fluid inlet hole inside the tool holder. The end of the shank must be square and have a good finish to make a good seal. To seal the center-flush hole, apply an upward pressure when inserting the tool.

ASSIGNMENT:

1. What is the depth of the tool holder?

2. What size must the shank of the tool be?

3. Why is it important that the end of the shank be square and smooth?

4. What is the largest diameter of flush hole possible to use in center-flushing?

UNIT V

OPERATING PROCEDURES

The Depth Stop — Lesson 7

OBJECTIVE:

To learn how to set the depth stop.

INFORMATION:

The Acu-Ram is provided with a circular vernier scale with a travel from 0 to 5 inches. Each inch is divided into 1/10 increments; each increment is divided into four equal parts of .025 inches. The adjustable pointer includes a vernier scale of 25 equal parts which will subdivide the .025 distance between two lines into 25 equal parts or .001 gradations.

The depth stop may be set to the desired setting within .001 inch by turning the knob located in the center of the operating panel (24). The depth of cut is obtained by setting the pointer of the depth-stop knob on any decimal dimension above zero. The number selected indicates the distance the quill will travel to reach zero.

Index the tool on the top surface of the workpiece and set the desired depth of cut on the depth stop dial.

VOCABULARY:

1. index
2. increment
3. subdivide
4. dry run

ASSIGNMENT:

By means of a dry run, set up tool and workpiece on machine. Bring tool and workpiece together by manual control. In turn, set depth-stop setting for a quill travel of 1.125", .875", .503" and .093".

UNIT V

OPERATING PROCEDURES

Startup Procedure

Lesson 8

OBJECTIVE:

To establish a startup procedure for electrical discharge machining.

INFORMATION AND DIRECTIONS:

1. Align and fasten workpiece to table.

2. Affix ground lead.

3. Turn the power-control switch to "power on".

4. Put right-hand wheel of quill assembly (16) in "rapid" position.

5. Bring quill down by holding left toggle switch (17) in "down" position and stop tool when near workpiece.

6. Put right hand wheel in neutral position.

7. Use manual-adjustment wheel and line up workpiece.

8. Select cutting range by *pulling out* selector knob (19).

9. Close overflow nozzles by turning clockwise (13).

10. Turn on pressure pump and fill tank.

11. Put right-hand wheel in servo position.

12. Pull guard down (15).

13. Put right toggle switch down and then turn power-control switch to "power-on-gap"; quill will start to descend.

14. When spark occurs, lift right toggle switch to the up position and turn power-control switch to "power on".

15. Set depth stop (24) and repeat step 13.

VOCABULARY:

affix

ASSIGNMENT:

Learn startup procedure and run through on the machine to the satisfaction of the instructor.

UNIT V

OPERATING PROCEDURES

Machining Efficiency Lesson 9

OBJECTIVE:

To understand machining efficiency.

INFORMATION:

Machining efficiency occurs at that machining rate when the most metal is being removed with the least amount of erratic behavior on the part of the quill assembly. A machining-efficiency meter (21) is used to show this condition visually. It is an indication of the voltage at the gap. The face of the indicator is divided into segments to indicate the machining efficiency. The best range of machining is located in the middle third of the scale and is considered the optimum area. The meter reading is adjusted by turning the gap-voltage knob (20). This knob controls the operating voltage of the Acu-Ram and thus controls the machining efficiency.

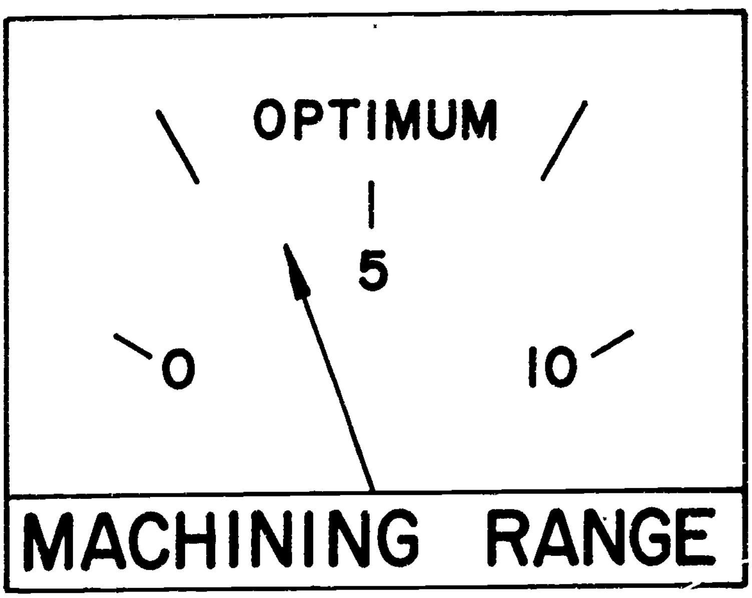


FIG. 5-1

For optimum machining, the needle on the meter should hold a steady value towards the left extremity of the optimum machining region. It will not always be possible to get this setting. In that case, adjust the needle as far to the left as possible. For difficult configurations and for "digging in" where a great amount of servo instability exists, the needle should be at the right extremity of the optimum machining region.

VOCABULARY:

1. efficiency
2. optimum
3. extremity
4. instability

ASSIGNMENT:

Discuss machining efficiency by defining efficiency, describing the efficiency meter, and outlining the function of the gap-voltage adjusting control.

UNIT V

OPERATING PROCEDURES

Care of Machine | Lesson 10

OBJECTIVE:

To establish steps to clean and care for machine.

INFORMATION:

The only items needed to clean an electro-discharge machine are a supply of absorbent wipers and a paint brush. The outside of the machine requires little attention. Simply wipe it down as needed. The work tank and workhead present the only cleaning problem. The debris from the sparking area is suspended in the dielectric fluid and is circulated through a filter.

However, by the nature of the debris, much of it settles out on the inside of the work tank, on the worktable, and on that part of the workhead which is submerged in the fluid. A paint brush wiped over the deposits will easily break them free where they can be flushed into the drain lines and eliminated.

ASSIGNMENT:

Clean the machine after each use.

UNIT V

OPERATING PROCEDURES

Safety

Lesson 11

OBJECTIVE:

To establish safety procedures for the EDM machine.

INFORMATION:

Unlike the metal-turning and chip-producing machines common to a machine shop, there are few hazards in electro-discharge machining. The liquid-level interlock is a safety device to protect the machine. The protective guard attached to the front of the quill assembly is there to protect the operator. The guard must be lowered in order to obtain voltage on the tool.

Rule 1. *Under no condition should the operator attempt to touch the tool electrode when the guard is down.*

Rule 2. *Never, never break Rule 1.*

ASSIGNMENT:

From what hazard does Rule 1 protect the operator?

UNIT V

OPERATING PROCEDURES

ACHIEVEMENT TEST

1. What is meant by nomenclature?
2. What is the function of the work tank?
3. What three settings are on the power-control switch?
4. What is polarity?
5. What is the function of the liquid-level interlock?
6. Give the specifications for a good tool shank.
7. Describe the depth-stop scale.
8. How is the cutting range set on an Acu-Ram?
9. Sketch a machining efficiency meter.
10. List the items needed to care for and clean the Acu-Ram.
11. Give the second safety rule for operating the Acu-Ram.

SETUP METHODS

X, Y, and Z Movements

Lesson 1

OBJECTIVE:

To define X, Y, and Z movements and relate them to the milling machine.

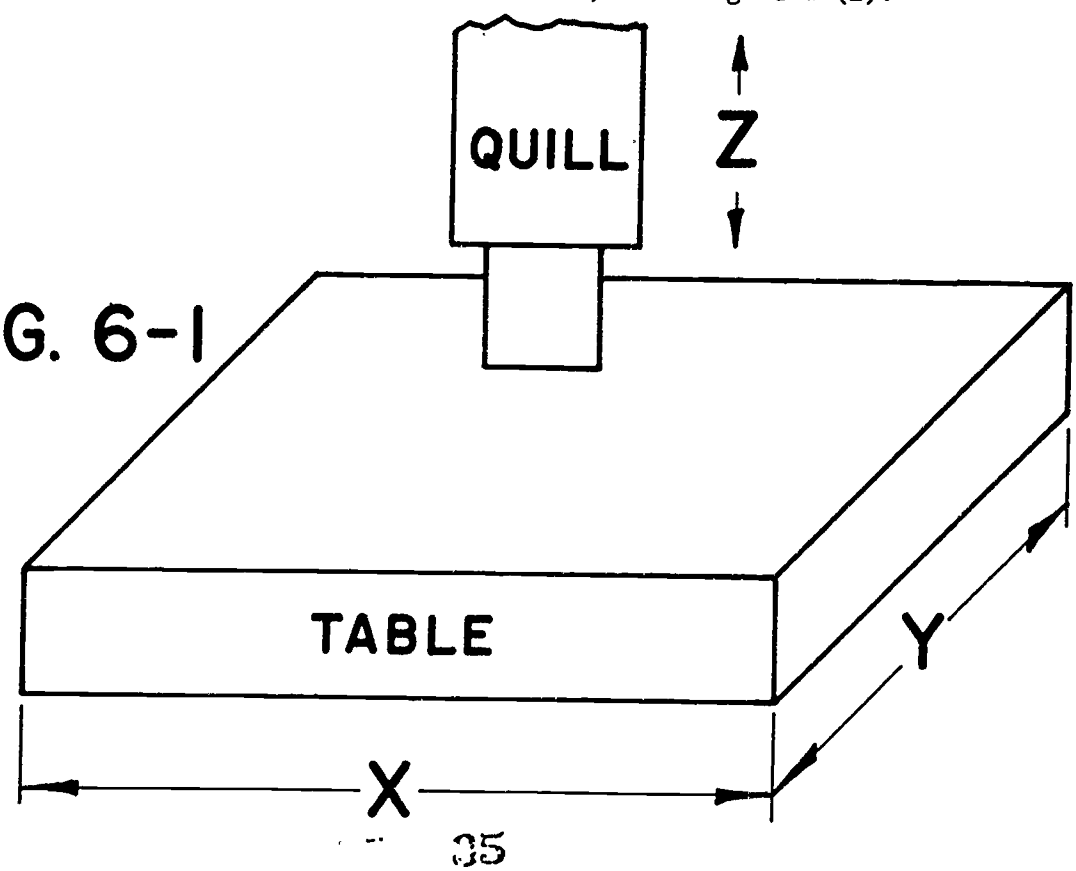
INFORMATION:

The skills and knowledge of setup and locating methods used on milling machines can be used to good advantage on an EDM machine. We shall discuss several methods of setup and locating procedures in this unit.

There are three basic straight-line movements that may be made on an EDM machine or a milling machine. The table will move lengthwise, or longitudinally across the face of the column of the machine. It will move transversely along the knee of the machine or at a 90° angle to the longitudinal movement. A vertical, or up-and-down movement, is provided by raising and lowering the table in a direction perpendicular to the table or, as is the case with an EDM machine, by advancing or retracting a quill assembly. A similar movement is made in the quill assembly of a Bridgeport machine.

For briefness, the longitudinal movement is designated (X).
The transverse movement is designated (Y).
The up-and-down, or vertical movement, is designated (Z).

FIG. 6-1



VOCABULARY:

1. longitudinal
2. transverse

ASSIGNMENT:

What movements do the letters X, Y, and Z refer to?

SETUP METHODS

Parallel Setup | Lesson 2

OBJECTIVE:

To learn how to set the job and the tool parallel to the X and Y movements of the machine.

INFORMATION:

To set the job parallel with the X movement, the indicator must be mounted on the quill assembly. By moving the job past the indicator, the job may be positioned with ease. The same procedure will serve for the Y movement. The Z setup must be established by moving the quill up and down.

To set a square tool up to the same movements, the indicator is mounted on the worktable and passed over the edges to be aligned.

ASSIGNMENT:

Perform the above setup in both the X and Y movements.

The Depth Micrometer and the Setup Lesson 3

OBJECTIVE:

To relate the depth micrometer to the EDM setup and tool location.

INFORMATION:

The use of a depth micrometer presupposes two things: that the workpiece has finished edges 90° to each other, and that the workpiece is parallel to the X movement. To position the tool by this method, three things must be known:

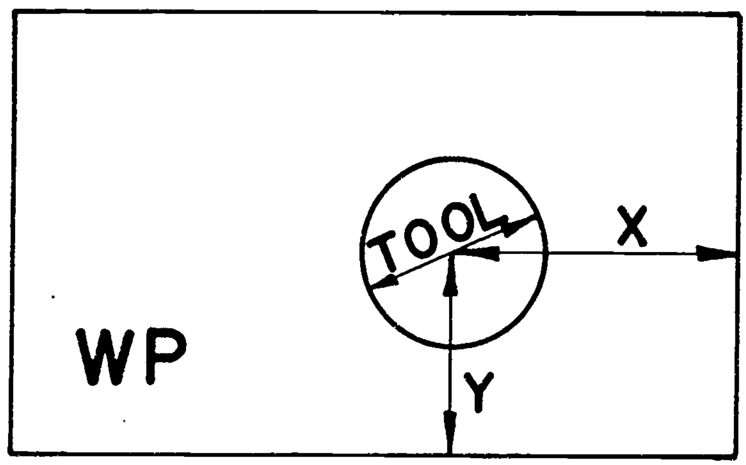


FIG. 6-2

1. The X dimension to the center of the hole.

2. The Y dimension to the center of the hole.

3. The dimensions of the tool.

If the tool is round, subtract 1/2 the diameter of the tool from the X movement to establish the micrometer setting. Do the same for the Y movement. By careful manipulation of the hand wheels, the workpiece may be easily positioned under the tool. If the tool is square or rectangular, determine the dimension of the tool from a center line running through the quill, and establish the depth micrometer settings in the same way.

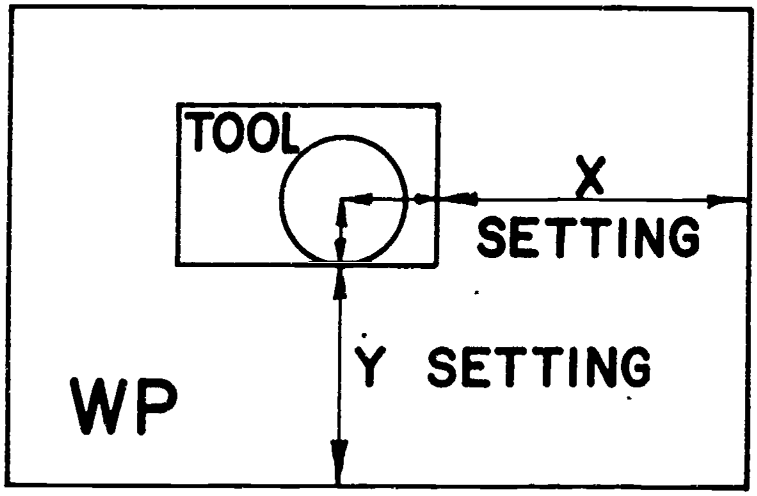


FIG. 6-3

VOCABULARY:

presuppose

ASSIGNMENT:

On a 4.000" x 8.000" workpiece with finished edges, locate a 3/4" round tool electrode in the exact center of the piece. What will be the micrometer settings?

Standard Shank Size | Lesson 4

OBJECTIVE:

To emphasize and illustrate the importance of a standard shank size to hole location.

INFORMATION:

The tool is held in the workhead tool holder by a set screw which when tightened forces the shank of the tool into position against the two sides of a fixed 90° V-shaped jaw.

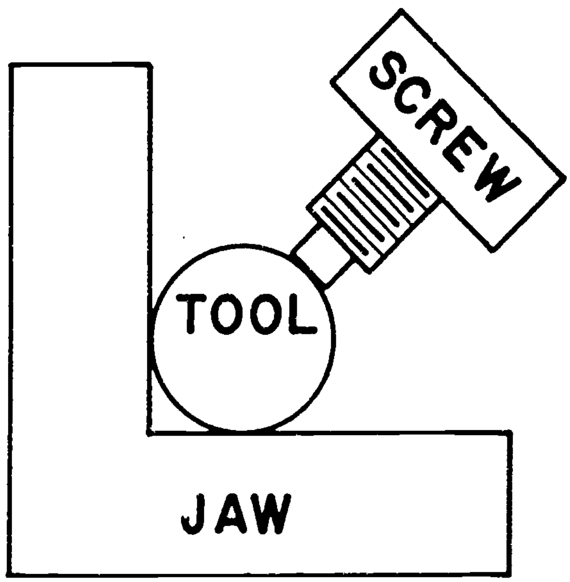
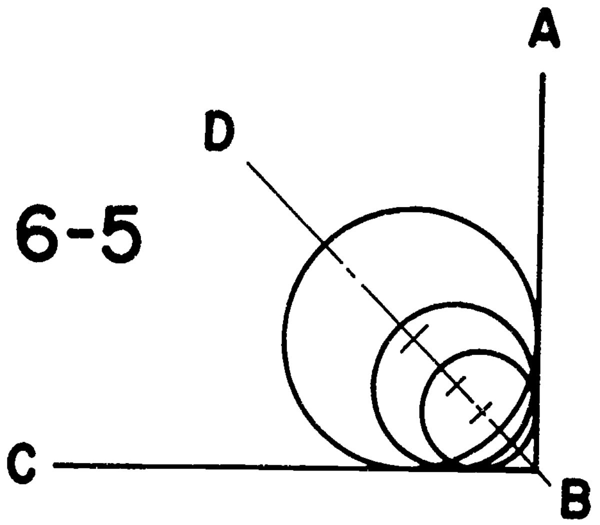


FIG. 6-4

This type of clamp is simple but effective. It provides three-point contact for clamping forces. However, since two points are always fixed, it makes it mandatory that all shanks be the same size if tools are to be exchanged without losing the centers of previously machined holes. This situation is likely to occur with a rough and then a finish cut. The certainty of error is illustrated in Fig. 6-5.

FIG. 6-5



As can be seen, as the shank decreases in size, the center of the tool electrode moves away from its original setting toward point B, a distance easily determined by multiplying the difference in diameter by the constant 1.21.

VOCABULARY:

mandatory

ASSIGNMENT:

Determine the amount of movement away from an established center the following differences in sizes will make and the direction of the movement from an established center on a diameter of .625 to

(a) diameter of .628
(b) diameter of .623
(c) diameter of .599

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The Setup Using a Tool Guide Lesson 5

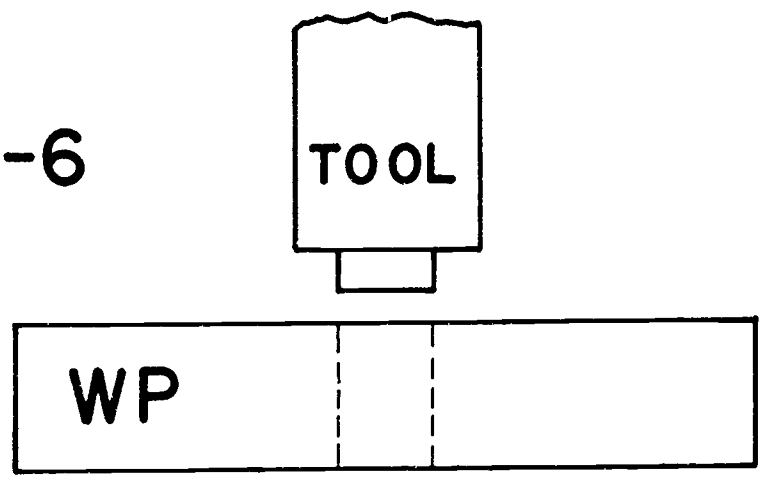
OBJECTIVE:

To learn to set up by through-hole and tool guide.

INFORMATION:

At times in the EDM process, it is necessary to align or realign to an existing hole. Also, the requirements for machining a hole may be very critical. One solution to this problem is to turn a guide or button of the exact size of the existing hole on the end of the tool.

FIG. 6-6



Mount the tool, but leave the job free to move on the table. Bring the tool electrode down until it enters the through-hole or the guide. Then fasten the job in position. Restart the tool and proceed with the machining operation.

ASSIGNMENT:

Practice this type of setup.

UNIT VI

SETUP METHODS

The Setup When Tool Sizes and Hole Dimensions Are Known

Lesson 6

OBJECTIVE:

To show how to use known sizes of tool and job to establish location.

INFORMATION:

When the diameter of the tool is known, or the distance from the center of the tool to the outer edge is known, a machining location is easily found *if* the workpiece has two machined edges at 90° to each other.

STEPS:

1. Set up job parallel to X movement.

2. Set up tool and determine distance from center to edge. With a round tool, this will be 1/2 the diameter.

3. Lower the tool so that it extends below the surface of the workpiece, at the end of the workpiece.

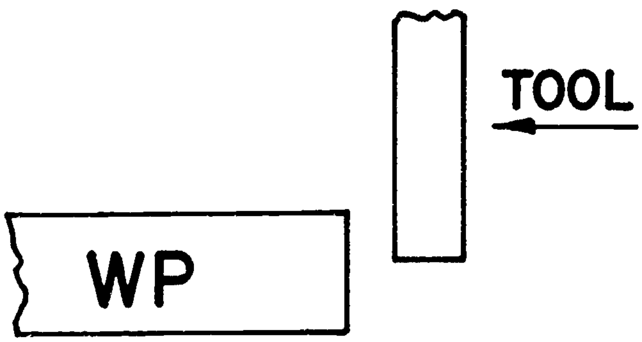


FIG. 6-7

4. With the hand wheel, move the tool towards the workpiece until a definite measurement may be made with a feeler or a narrow strip of paper between the tool and workpiece.

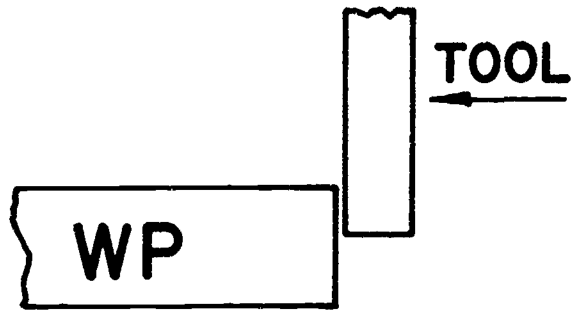


FIG. 6-8

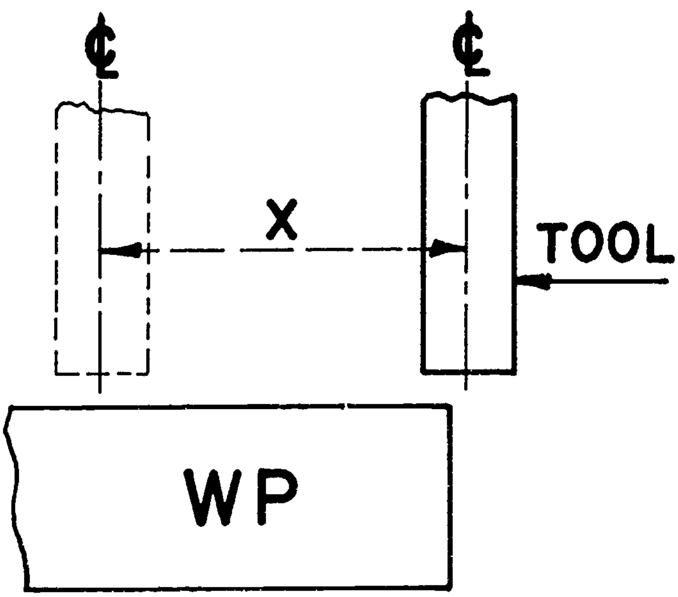


FIG. 6-9

5. Remember the feeler dimension. Raise the quill to clear the tool over the workpiece.

6. Add the X movement from the edge of the workpiece to the machining location, the feeler thickness, and the dimension of the tool from the center to the edge.

7. On the X hand-wheel, move the tool the calculated distance.

8. Lock the clamp on the X travel gib.

9. On the transverse (Y) hand-wheel, move the tool to clear the edge of the workpiece.

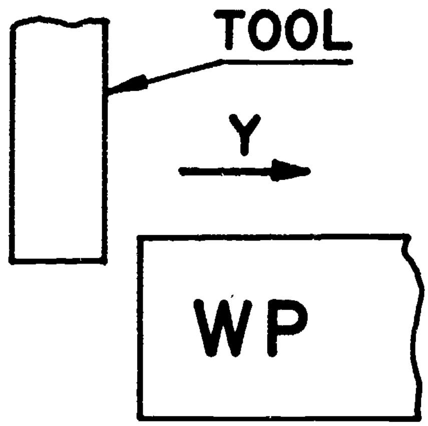


FIG. 6-10

10. Repeat steps 3 to 5.

11. Add the (Y) movement from the edge of the workpiece to the machining location, the feeler thickness, and the dimension of the tool from center to edge.

12. On the Y hand-wheel, move the tool the calculated distance.

13. Lock the clamp on the Y travel gib. The tool is now in position for machining.

ASSIGNMENT:

Practice this setup by locating a 1.000-inch tool 2.000 inches from the side and end of a 90° workpiece.

UNIT VI

SETUP METHODS

ACHIEVEMENT TEST

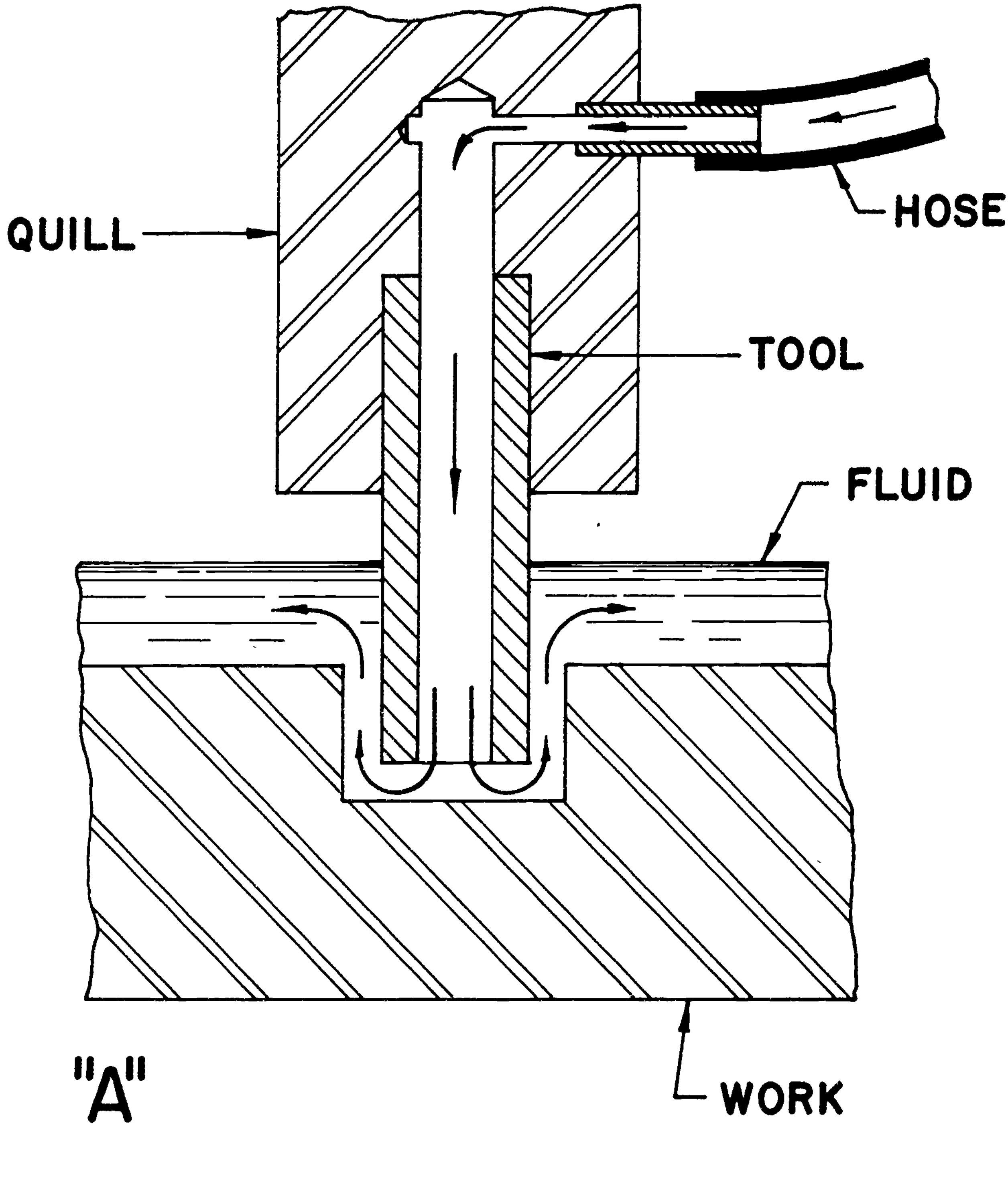
1. What system of coordinates do the X, Y, and Z movements refer to?

2. What letter movement is indicated when the term "longitudinal" is used?

3. With what center line on the machine must the center line in a tool shank correspond, if tools are to be interchanged?

4. By what constant can the amount of movement in different shank sizes be calculated?

5. Give the procedure for setting up and locating a machining area when the tool size and hole-locating dimensions are known.



CENTER-FLUSH PRESSURE

FIG. 7-1

UNIT VII

FLUSHING METHODS

Center Flush, Pressure, Method "A" Lesson 1

OBJECTIVE:

To learn to use pressure flushing in the EDM process.

INFORMATION:

Proper flushing is central to the EDM process. Flushing may be done in four ways. We will consider each in turn. The choice of the flushing method depends on the particular job.

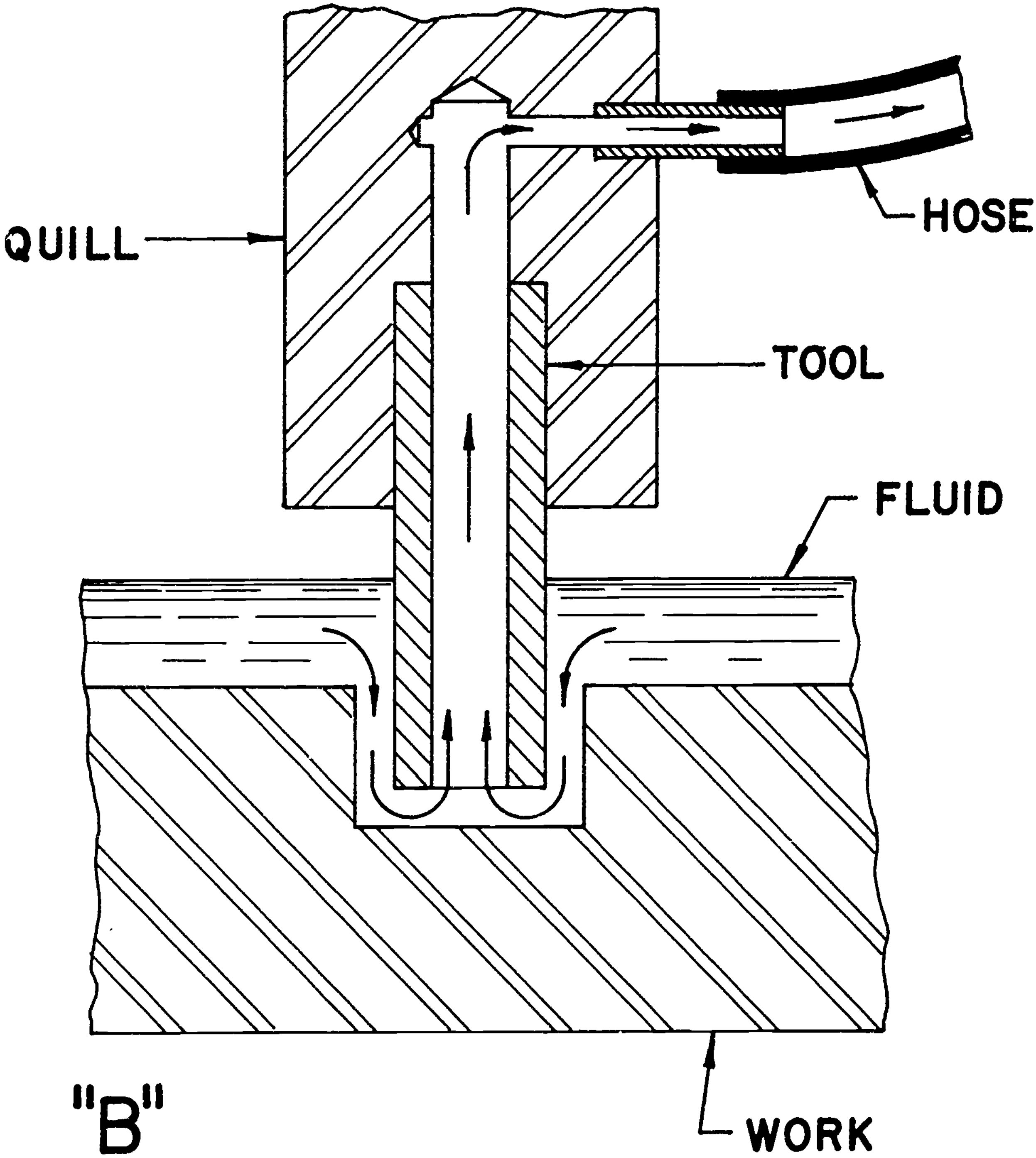
In this method, as can be seen in Fig. 7-1, the pressure pump forces the fluid into the connection on the quill, down through a hollow-tool electrode, and across the region of sparking. This is an effective flushing method. However, a small boss or nub is left on the workpiece opposite the opening in the tool electrode. In a through-hole, the nub causes no problem. In a blind hole, the nub must be removed by a solid tool of appropriate size.

VOCABULARY:

nub

ASSIGNMENT:

Trace the flow of liquid in Method "A".



"B"

CENTER-FLUSH VACUUM
FIG. 7-2

UNIT VII

FLUSHING METHODS

Center Flush, Vacuum, Method "B" Lesson 2

OBJECTIVE:

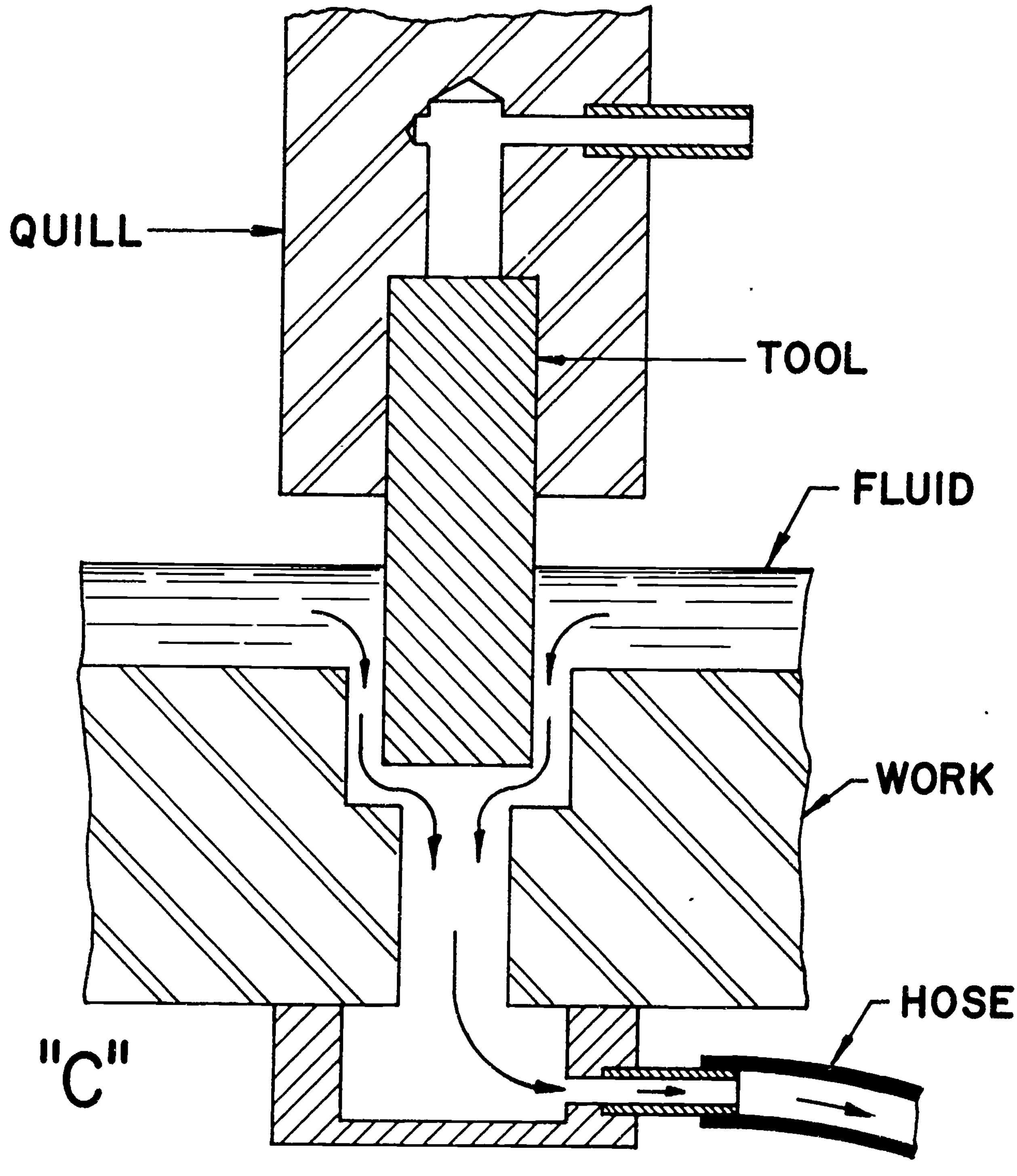
To learn to use vacuum flushing in the EDM process.

INFORMATION:

In Method "B", the physical setup is the same as in Method "A" with one exception. The flow of the fluid is reversed by connecting a vacuum hose to the quill connection. This method has the same advantages and disadvantages as Method "A". Its use is a matter of choice for the operator.

ASSIGNMENT:

Trace the flow of fluid in Method "B".



VACUUM FLUSH

FIG. 7-3

Vacuum Flush for Through-Holes, Method "C" Lesson 3

OBJECTIVE:

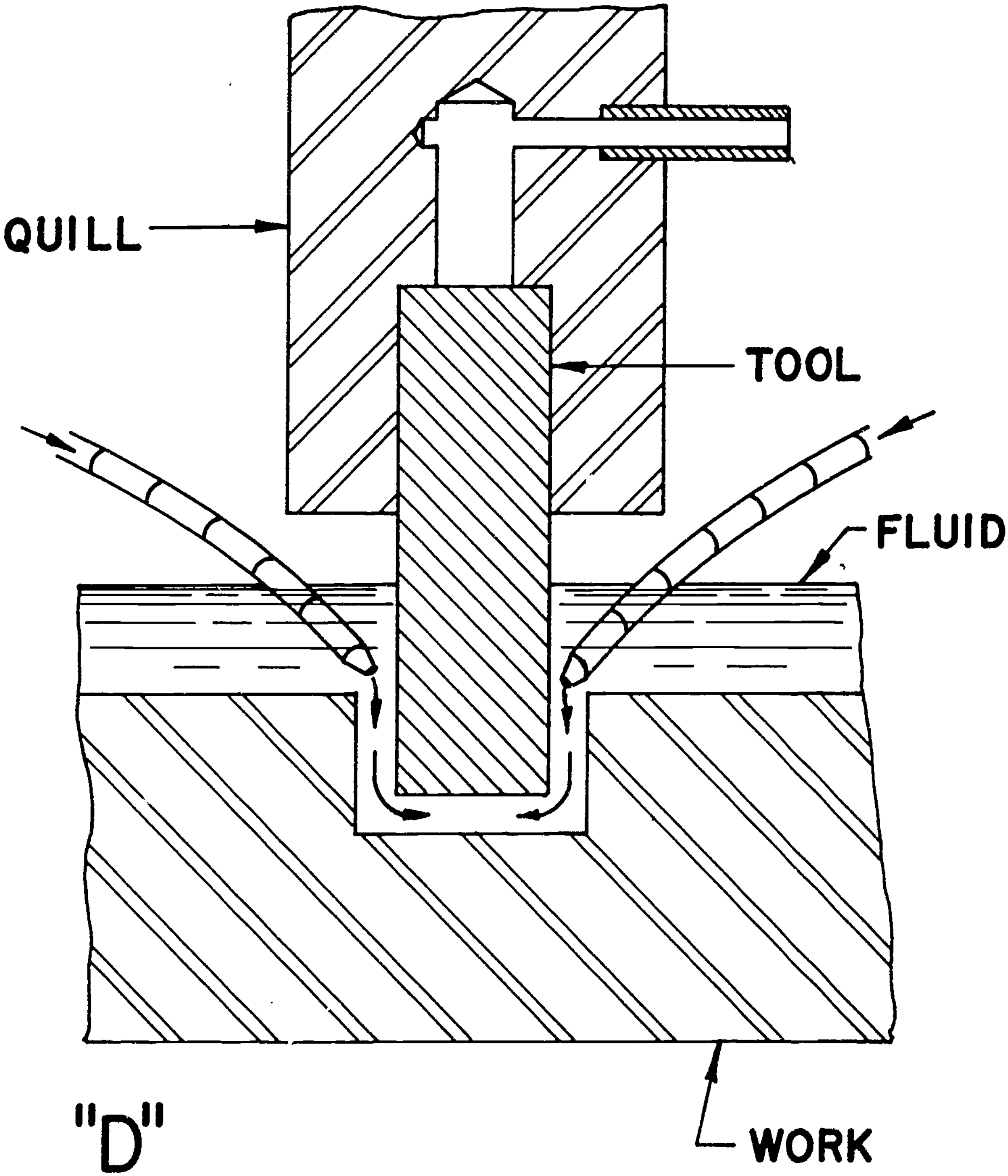
To learn to use vacuum flushing in through-holes in the EDM process.

INFORMATION:

Method "C" is the best flushing method of the four methods discussed in this unit. It provides an uninterrupted, large-volume flow of fluid across the sparking area of a workpiece. It is used when a through-hole exists through a workpiece. The workpiece is mounted over a vacuum chamber which has the vacuum line attached to it. The vacuum pump pulls the fluid from the work tank, across the region of sparking, through the existing hole in the workpiece, and into the vacuum chamber.

ASSIGNMENT:

Trace the flow of fluid in Method "C".



JET FLUSH
FIG. 7-4

UNIT VII

FLUSHING METHODS

Jet Flush, Method "D" Lesson 4

OBJECTIVE:

To learn to use jet flushing in blind holes.

INFORMATION:

Flushing method "D" is the least satisfactory of the flushing methods.

It should be avoided when possible. Method "D" is used for jobs in which there is no initial hole in either the tool or the workpiece. The machining of cavities sometimes requires this method, however. In this method, pressure hoses are directed toward the machining region, and the fluid is forced into the region of sparking. Quill movement is erratic, and much time is lost as the servo-mechanism constantly retracts the tool electrode so that debris may be washed away.

VOCABULARY:

erratic

ASSIGNMENT:

Trace the flow of fluid in Method "D".

ACHIEVEMENT TEST:

Discuss the advantages and disadvantages of each method of flushing.

UNIT VII

FLUSHING METHODS

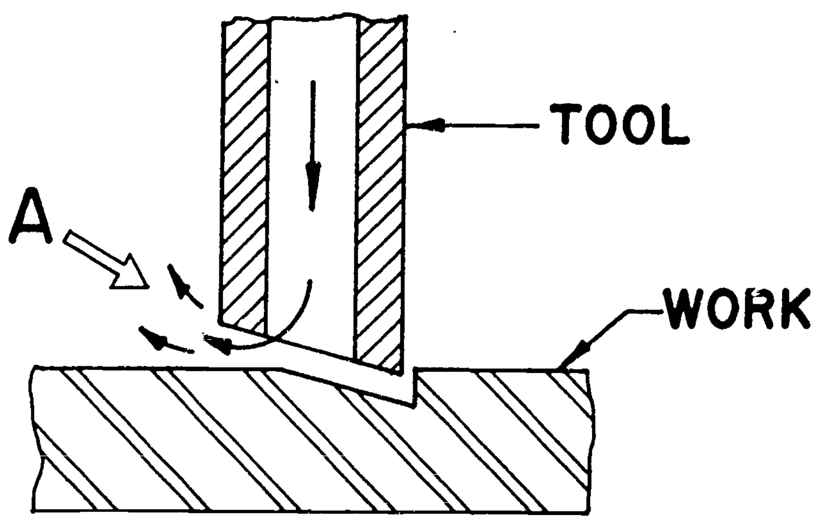
"Digging In" and "Breaking Through" Lesson 5

OBJECTIVE:

To learn of the problems of "digging in" and "breaking through."

INFORMATION:

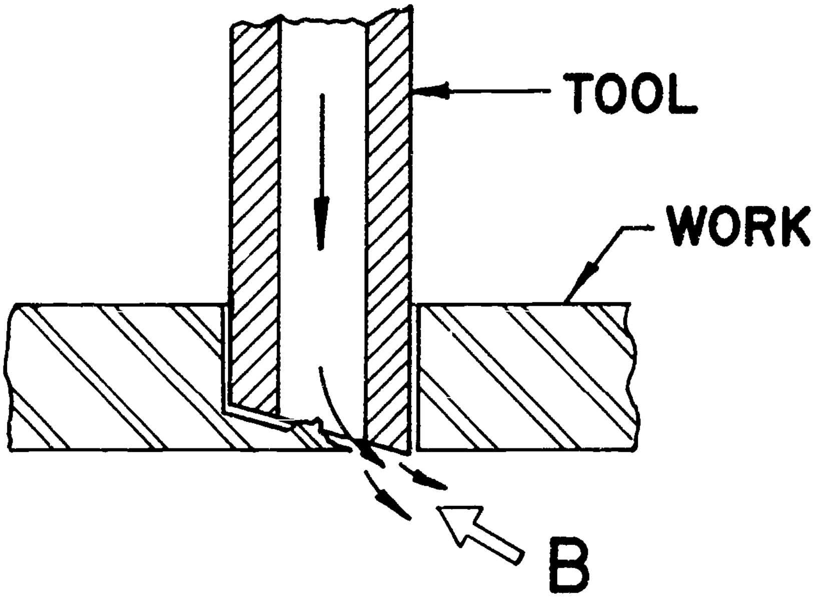
During the first few minutes of starting of most EDM jobs, the tool is being "seated" in the surface of the workpiece. During this time the servo-mechanism will behave erratically. Poor flushing is the cause of this behavior. During this period the surface of the tool does not conform to the surface of the workpiece. Hence, the tool must retract to clear the work area of debris. An exaggerated view is shown in Fig. 7-5.



DIGGING IN

FIG. 7-5

Frequently, a similar condition will exist as the tool breaks through at the bottom of the workpiece. Once again, poor flushing is to blame, as shown in Fig. 7-6.



BREAKING THRU
FIG. 7-6

This condition will continue until the hole is cleared out or cleaned up.

ASSIGNMENT:

By sketch, illustrate the two conditions shown above.

ACHIEVEMENT TEST

1. Why is flushing so important to the EDM process?

2. Why have four methods been developed for flushing?

3. Why do blind holes take longer to machine than through-holes, if the volume of metal removed is the same?

4. Discuss "digging in" and "breaking through."

UNIT VIII

MACHINING PARAMETERS

Tool Wear Factors (First Pass) Lesson 1

OBJECTIVE:

To learn of tool wear and the factors to be considered in tool-wear economics of the EDM process.

INFORMATION:

In this unit, we will be concerned with tool wear, metal-removal rates, finishes, and overcuts.

The amount of tool wear in the EDM process depends upon several factors. Among those factors are: tool material, work material, and machining current. A tool wears in two ways; they are edge wear and volume wear. Both are measured in ratio to the amount of metal removed from the workpiece. Both ratios are important when considering the amount of wear in EDM.

In considering the tool-wear economics of an EDM job, the following factors are considered:

1. Cost of tool electrode material.

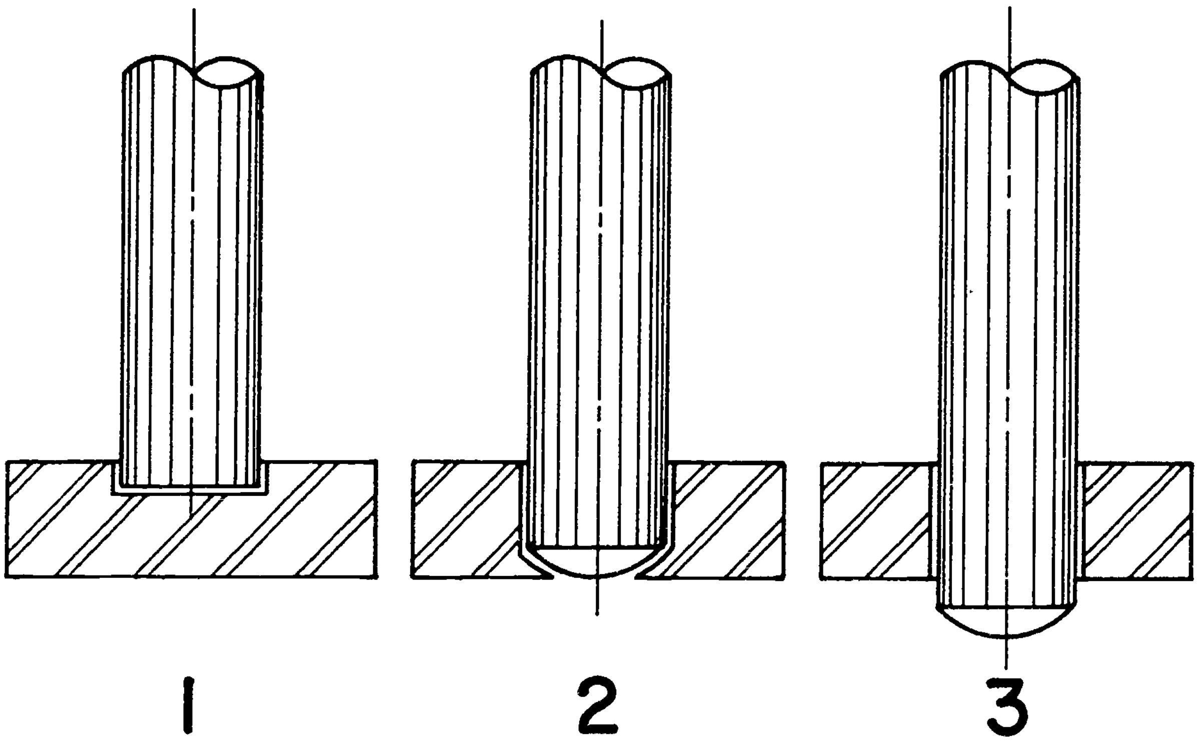
2. The cost of forming or fabrication is included in this cost.

3. The edge-wear ratio of the tool material.

4. The volume-wear ratio of the tool material.

The edge-wear ratio describes the amount of rounding of the sharp corners at the end of the tool. In the case of through-hole jobs, the rounding of the corners of the tool causes the center to "break through" the workpiece first. Therefore, it is necessary to continue the travel of the tool until the sides of the hole become parallel.

It can be seen from the sketches that the tool electrode must be longer than the workpiece. The edge-wear ratio of the tool material determines the amount of over-travel necessary for a straight hole. Frequently, it is necessary to redress a tool after each operation.



THREE STAGES
OF A THRU HOLE

FIG. 8-1

VOCABULARY:

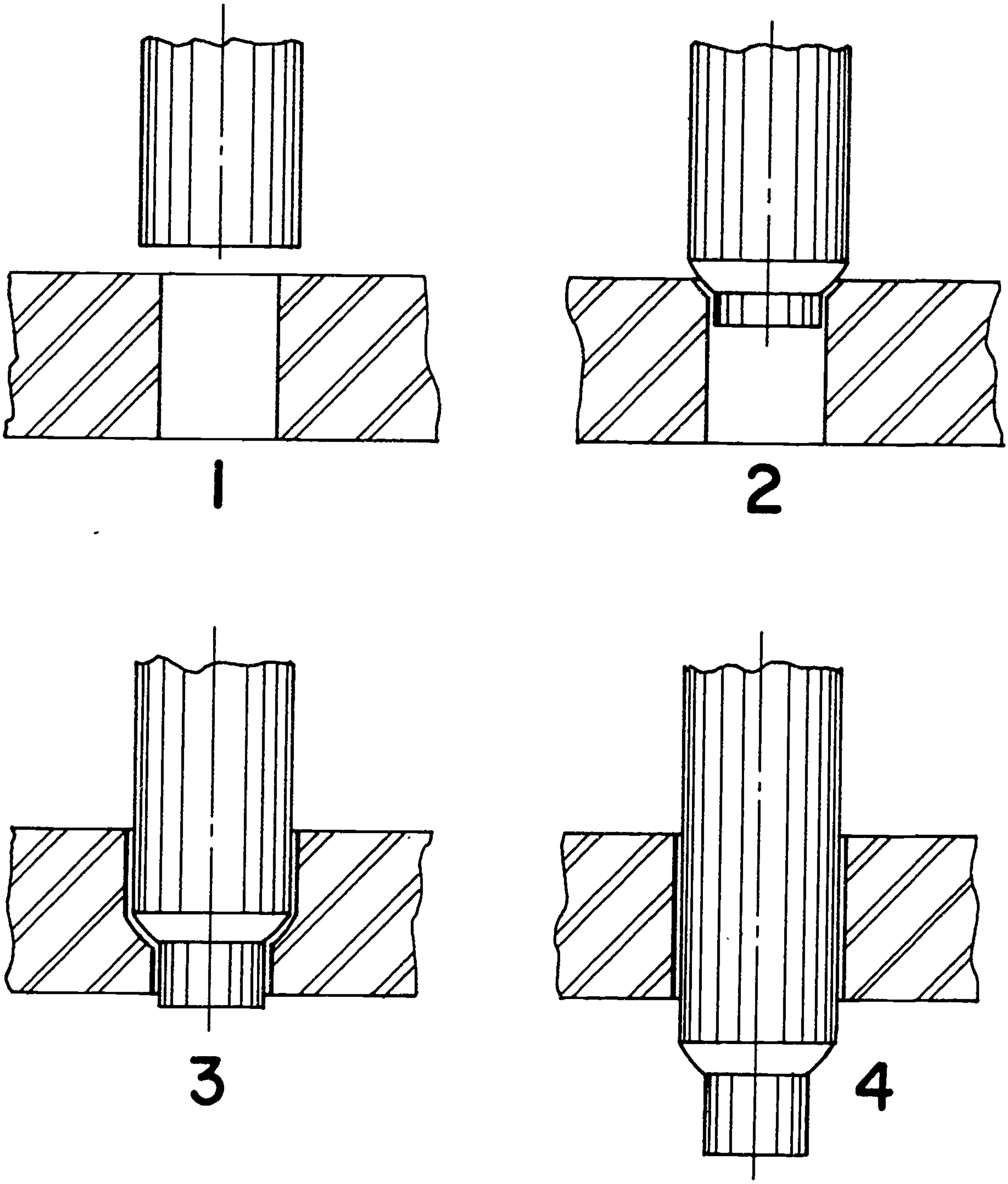
1. parameter
2. fabrication
3. over-travel
4. redress

ASSIGNMENT:

1. What factors are considered when selecting a tool material for an EDM job?

2. Why should the cost of preparing a tool be considered in selecting a tool material?

3. How does over-travel increase the cost of a job?



TOOL WEAR
"THRU HOLE" (2nd PASS)
FIG. 8-2

UNIT VIII

MACHINING PARAMETERS

Tool Wear Factors (Second Pass) Lesson 2

OBJECTIVE:

To learn about tool wear and the factors to be considered in tool wear during a second pass (cut).

INFORMATION:

In a situation where electrical discharge machining is performed and a through-hole exists, the effects of tool wear are more complicated.

It can be seen from the sketches that the corners of the tool become rounded as in the first case. However, there is an area at the end of the tool that does no machining. It retains its original shape, and room must be provided for it during the set-up. A high rate of wear on a tool means extra space under the workpiece.

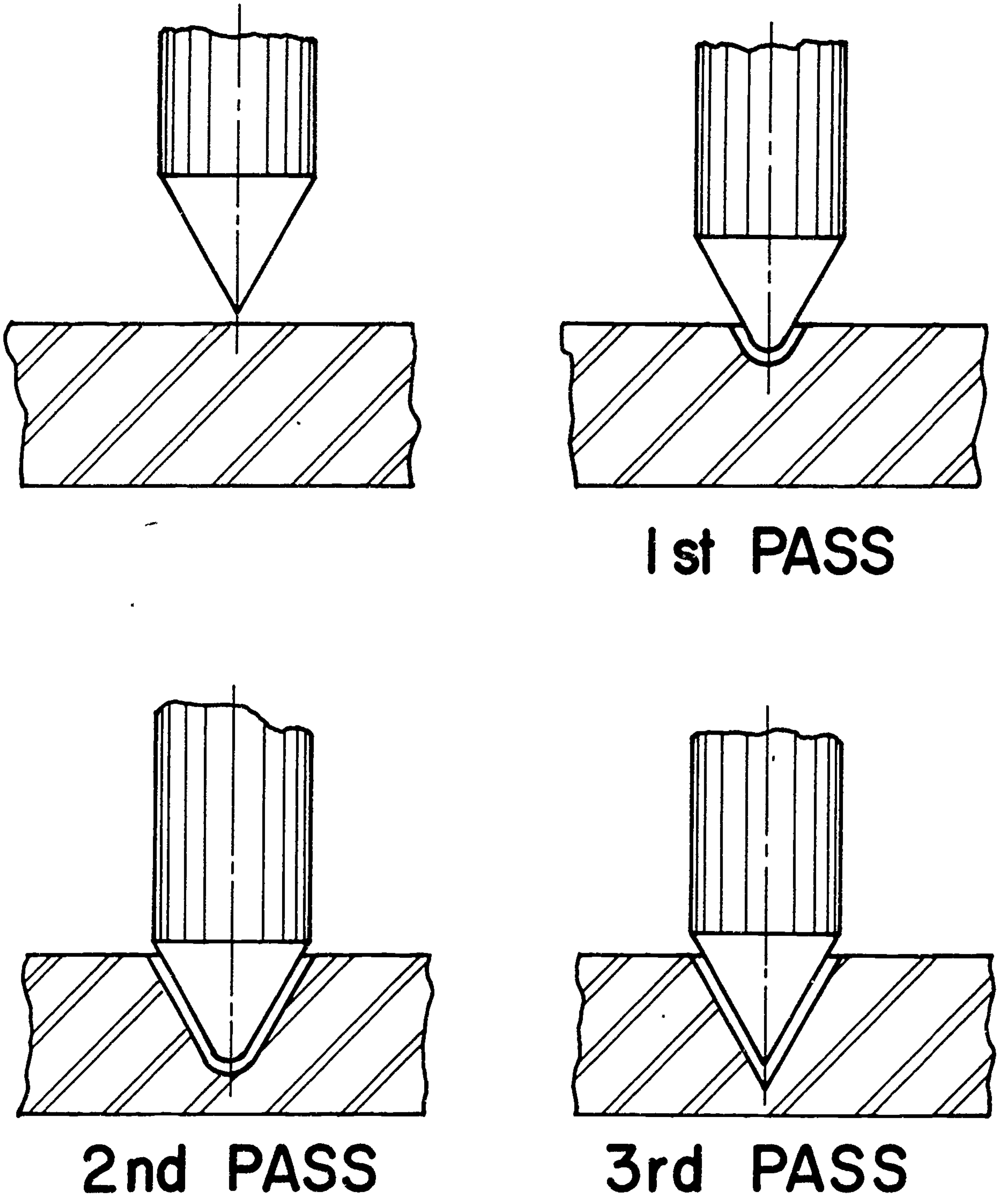
For through-holes, it is usually not important to achieve low edge wear if the tool can be easily fabricated from bar stock. Yellow brass is comparatively inexpensive and easily fabricated and in many instances is ideal for a through-hole tool.

VOCABULARY:

1. second pass
2. configuration

ASSIGNMENT:

How does the final configuration of a used second-pass tool differ from that of a first-pass tool?



TOOL WEAR IN BLIND HOLE

FIG. 8-3

Tool Wear Factors (Blind Holes) Lesson 3

OBJECTIVE:

To consider edge-wear ratio and the blind hole.

INFORMATION:

In the case of "blind holes" or cavities, the edge-wear ratio is more critical than it is in the case of through-holes. Here, a low-edge-wear material is more economical than one which must be redressed frequently.

VOCABULARY:

blind hole

ASSIGNMENT:

Contrast the importance of edge-wear ratios in through-hole machining and blind-hole machining.

UNIT VIII

MACHINING PARAMETERS

Volume Tool Wear and Tool Materials | Lesson 4

OBJECTIVE:

To learn about tool materials and volume wear.

INFORMATION:

The volume tool-wear ratio is defined as the ratio of the volume of work machined in a given job to the volume of tool eroded in the same job. For instance, a tool-wear ratio of 3:1 means that the volume of work machined is three times as great as the volume of tool eroded.

The following table better illustrates the example:

Tool Material	Wear Ratio
Yellow brass	1.3:1
Graphite (dense)	3.4:1
Copper tungsten	8.7:1
Copper graphite	4.5:1

VOCABULARY:

dense

ASSIGNMENT

Define volume wear ratio.

UNIT VIII

MACHINING PARAMETERS

Over-Cuts — Lesson 5

OBJECTIVE:

To define over-cut and to recognize over-cutting as a factor to be considered in EDM.

INFORMATION:

Over-cut is the space or gap produced between the electrode and the workpiece by the requirement of EDM that there must be a set space in which sparking may occur. Over-cut occurs at the sides of the electrode and is always twice the gap spacing. The dimensions of the over-cut are fixed by the combination of two factors, amperage and voltage-- a combination predetermined by each position of the "finish selector" switch.

The following table shows values of the over-cut for each finish setting using vacuum flushing in a through-hole.

Setting	Over-cut
Ultra-Fine	.0015 inches
Extra-Fine	.0025 inches
Fine	.004 inches
Medium	.008 inches
Coarse	.014 inches

It cannot be stressed too strongly that all values depend on good dielectric flushing of the machining area. Poor flushing increases both over-cuts and machining time.

VOCABULARY:

over-cut

ASSIGNMENT:

1. A tool is 1.986" in diameter and the hole it creates is 2.000" in diameter. What is the tool clearance on each side of the tool?

2. Under ideal machining conditions, what was the machining setting on the finish selector?

Metal Removal Rates and Surface Finishes — Lesson 6

OBJECTIVE:

To learn to relate metal-removal rates to surface finishes.

INFORMATION:

In the EDM process, the metal-removal rate and surface finish are closely related. In general, high metal-removal rates are associated with coarse surface finishes. The reverse holds true for fine finishes.

Metal-removal rates are given in cubic inches per hour and have little to do with the size and shape of the machined cavity. The surface finish of an EDM surface is usually given in R.M.S. (root mean square) microinches.

Composition of the tool, or the workpiece, or machining configuration, may cause small differences in machine finishes. At any given setting, a carbide workpiece will give a better finish than any steel alloy.

VOCABULARY:

R.M.S.

ASSIGNMENT:

Think of a situation where the configuration of the tool might affect the surface finish of a job. Explain your reasoning.

UNIT VIII

MACHINING PARAMETERS

Finishes — Lesson 7

OBJECTIVE:

To relate descriptive finishes to measurable finishes (microinches).

INFORMATION:

The settings on the EDM machine are usually given as *ultra-fine, extra-fine, fine, medium,* and *coarse.* Words mean different things to different people. However, when words are related to definite standards of measurement, it lessens the chance for mistakes. Here the words are defined in microinches.

Finish Setting	Microinches (R.M.S.)
Ultra-Fine	20
Extra-Fine	42
Fine	110
Medium	200
Coarse	400

ASSIGNMENT:

What disadvantages do descriptive terms have in relation to definite sizes or conditions?

UNIT VIII

MACHINING PARAMETERS

ACHIEVEMENT TEST

1. What is edge wear?

2. What is volume wear?

3. Why does poor flushing increase the cost of a job?

4. In what terms is volume wear expressed?

5. Why is edge wear a major concern in "blind hole" machining?

6. What does a volume tool-wear ratio of 6:1 mean?

7. An EDM job was machined with a square tool 1" on a side. It took 24 hours to complete the job. A similar job is to be machined. The area of the tool to be used is 2" on a side. How long will it take to do the second job?

VOCABULARY

1. affix - to fasten to.
2. ampere - a unit of current.
3. anti-backlash - a device to prevent loss of movement in a gear when direction of rotation is made.
4. auxiliary - supplemental(help or service).
5. brittle - easily broken.
6. capacitor - device able to give large values of electrical capacity, a condenser.
7. circuit - a complete path of an electrical current.
8. crater - a bowl-shaped depression.
9. critical - marking a transitional point at which a final change takes place.
10. debris - rubbish, such as results from destruction.
11. de-energize - to cut off energy.
12. dense - having its parts massed or crowded together; close, compact.
13. derive - to gather by inference, deduce.
14. dielectric - non-conductor of electricity.
15. dry run - simulation, rehearsal, practice.
16. efficiency - effective operation as measured in cost of energy and time.
17. electrode - a conductor used to make contact with a non-metallic part of a circuit.
18. energy - capacity for performing work
19. erosion - destroying by slow disintegration.
20. erratic - having no certain course.
21. extremity - the utmost point or limit.
22. fabricate - to form by art and labor, to put together.

23. fragile - easily broken or destroyed.

24. function - the natural, proper, or characteristic action of a part.

25. generate - to originate, to produce.

26. hardness - degree of resistance to abrasion.

27. increment - one of a series of additions.

28. incubation - period of development.

29. index - to establish a reference point in machine work.

30. instability - lack of determination, inconstancy, lack of direction.

31. interlock - to connect in such a way that a circuit cannot be activated until a switch is in proper condition.

32. jogging - the act of moving a machine or machine part by short bursts of applied power.

33. longitudinal - lengthwise.

34. magnetic shunt - electrical—a conductor joining two points in a circuit so as to form a parallel or derived circuit through which a portion of current may pass, in order to regulate the amount passing in the main circuit; an electric control.

35. mandatory - obligated; of a necessity.

36. microswitch - small electrical switch used in automatic controls.

37. negative - charged with negative electricity; having an excess of electrons

38. nomenclature - terminology; technical terms applied to a specific subject.

39. nub - a knot or lump.

40. optimum - the most favorable, best

41. over-cut - a term used to indicate the space between the edge of a hole and the tool electrode.

42. overlap - to extend over and beyond.

43. over-travel - to travel beyond the machining area.

44. parameter - an independent variable through functions of which other functions may be expressed. A group of functions wherein the change of the value of one affects the value of the others.

45. polarity - the state of being either positive or negative electrically.

46. positive - charged with positive electricity.

47. predetermine - to determine in advance.

48. presuppose - to take for granted, previously established.

49. quill - movable part on EDM machine that contains the workhead and supplies vertical movement to the tool electrode.

50. redress - to re-machine or reform.

51. R.M.S. - root-mean-square, the square root of the arithmetical mean of the squares of a set of numbers. Standard deviation.

52. spark energizer- one of the basic components of the EDM machine.

53. specialize - to apply or restrict to a particular end, single purpose.

54. subdivide - to divide again.

55. transverse - running or lying across.

56. warpage - twisting or distortion.

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