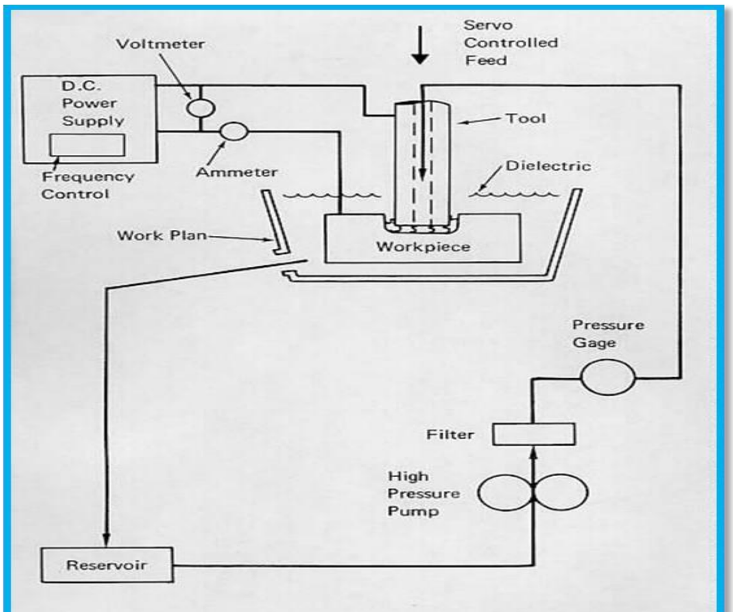
UNIT – III THERMO-ELECTRIC ENERGY BASED PROCESSES

Principle of electrical discharge machining with neat sketch.

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark.



Schematic of EDM Machine.

Introduction:

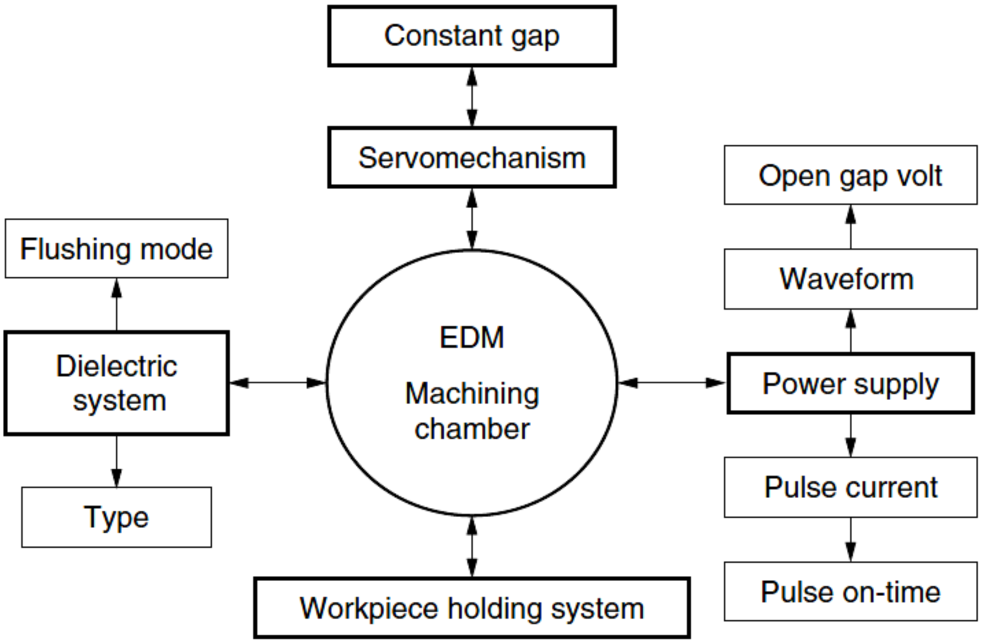
- It is also referred to as spark machining, spark eroding, burning, die sinking or wire erosion
- Its a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks).
- Material is removed from the workpiece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage.
- One of the electrodes – „tool-electrode" or „tool" or „electrode".
- Other electrode - workpiece-electrode or „workpiece".
- As distance between the two electrodes is reduced, the current intensity becomes greater than the strength of the dielectric (at least in some points) causing it to break.

EDM components:

The main components in EDM:

- Electric power supply
- Dielectric medium
- Work piece & tool
- Servo control unit.

- The work piece and tool are electrically connected to a DC power supply. The current density in the discharge of the channel is of the order of 10000 A/cm^2 and power density is nearly 500 MW/cm^2.



- A gap, known as SPARK GAP in the range, from 0.005 mm to 0.05 mm is maintained between the work piece and the tool. Dielectric slurry is forced through this gap at a pressure of 2 kgf/cm^2 or lesser.

Working Principle:

- It is a process of metal removal based on the principle of material removal by an interrupted electric spark discharge between the electrode tool and the work piece. In EDM, a potential difference is applied between the tool and workpiece.

- Essential - Both tool and work material are to be conductors. The tool and work material are immersed in a dielectric medium. Generally kerosene or deionised water is used as the dielectric medium.

- A gap is maintained between the tool and the workpiece. Depending upon the applied potential difference (50 to 450 V) and the gap between the tool and workpiece, an electric field would be established.

- Generally the tool is connected to the negative terminal (cathode) of the generator and the workpiece is connected to positive terminal (anode).As the electric field is established between the tool and the job, the free electrons on the tool are subjected to electrostatic forces.

- If the bonding energy of the electrons is less, electrons would be emitted from the tool. Such emission of electrons are called or termed as „cold emission‟. The "cold emitted" electrons are then accelerated towards the job through the dielectric medium. As they gain velocity and energy, and start moving towards the job, there would be collisions between the electrons and dielectric molecules. Such collision may result in ionization of the dielectric molecule.

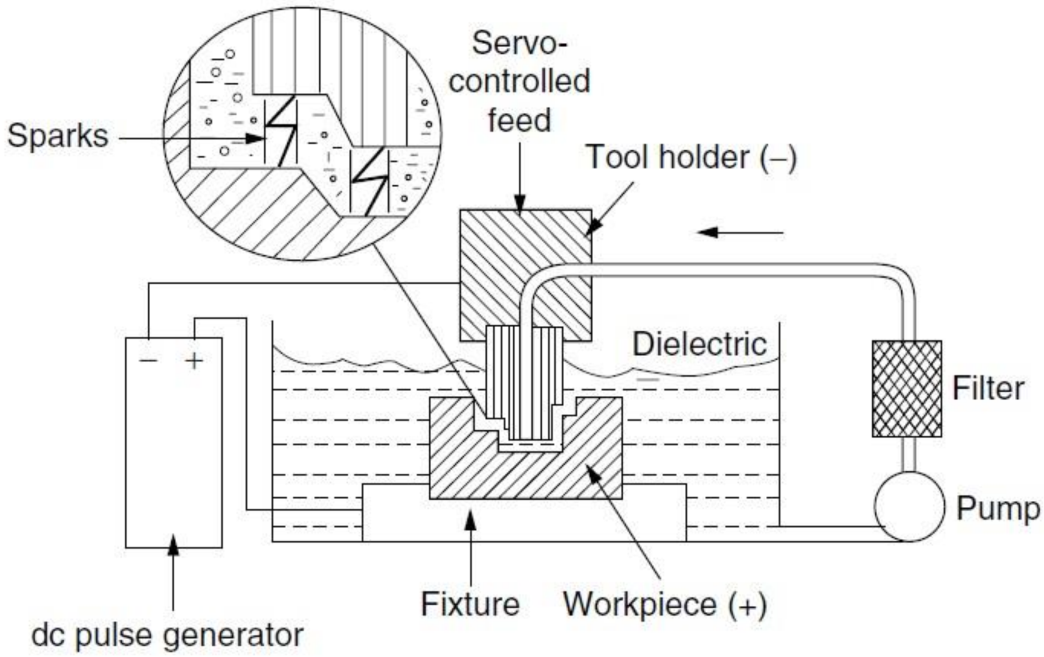
- Ionization depends on the ionization energy of the dielectric molecule and the energy of the electron. As the electrons get accelerated, more positive ions and electrons would get generated due to collisions. This cyclic process would increase the concentration of electrons and ions in the dielectric medium between the tool and the job at the spark gap.

- The concentration would be so high that the matter existing in that channel could be characterised as “plasma”. The electrical resistance of such plasma channel would be very less. Thus all of a sudden, a large number of electrons will flow from tool to job and ions from job to tool. This is called avalanche motion of electrons. Such movement of electrons and ions can be visually seen as a spark. Thus the electrical energy is dissipated as the thermal energy of the spark

- The high speed electrons then impinge on the job and ions on the tool. The kinetic energy of the electrons and ions on impact with the surface of the job and tool respectively would be converted into thermal energy or heat flux. Such intense localized heat flux leads to extreme instantaneous confined rise in temperature which would be in excess of 10,000°C. Such localized extreme risein temperature leads to material removal.

- Material removal occurs due to instant vaporization of the material as well as due to melting. The molten metal is not removed completely but only partially.

Additional Diagram:

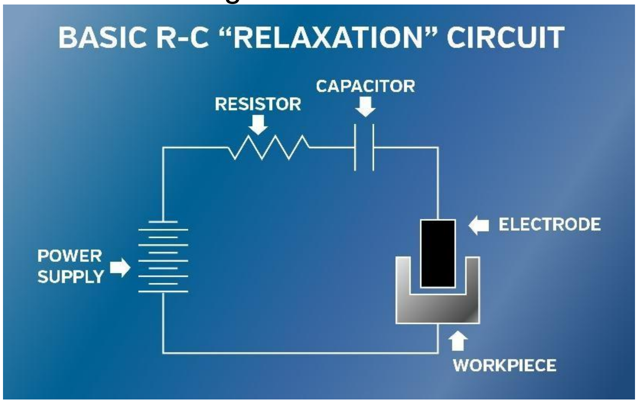


Classification and characteristics of various spark erosiongenerators.
EDM – Power & Control Circuits:

- Commercially available: RC circuits based, Rotary impulse generator, transistor controlled pulses.
  Types of circuits used in EDM can be classified into three groups:
  1) Resistance - Capacitance (RC) relaxation circuit with a constant dc source.
  2) Rotary Impulse Generator
  3) Controlled Pulse Circuit
- Two broad categories of generators (power supplies) are in use on EDM. In the first category, the main parameters to choose from at setup time are the resistance(s) of the resistor(s) and the capacitance(s) of the capacitor(s). In an ideal condition, these quantities would affect the maximum current delivered in a discharge.

- Current delivery in a discharge is associated with the charge accumulated on the capacitors at a certain moment. Little control is expected over the time of discharge, which is likely to depend on the actual spark-gap conditions.

- Advantage: RC circuit generator can allow the use of short discharge time more easily than the pulse-controlled generator.



- Also, the open circuit voltage (i.e. voltage between electrodes when dielectric is not broken) can be identified as steady state voltage of the RC circuit.In generators based on transistor control, the user is usually able to deliver a train of voltage pulses to the electrodes. Each pulse can be controlled in shape, for instance, quasi-rectangular.

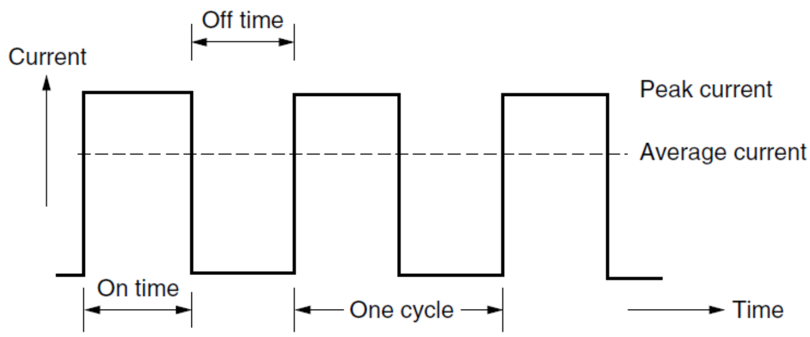
- In particular, the time between two consecutive pulses and the duration of each pulse can be set.The amplitude of each pulse constitutes the open circuit voltage. Thus, maximum duration of discharge is equal to duration of a voltage pulse.

- Maximum current during a discharge that the generator delivers can also be controlled. Details of generators and control systems on EDMs are not always easily available to their user. This is a barrier to describing the technological parameters of EDM process. Moreover, the parameters affecting the phenomena occurring between tool and electrode are also related to the motion controller of the electrodes.

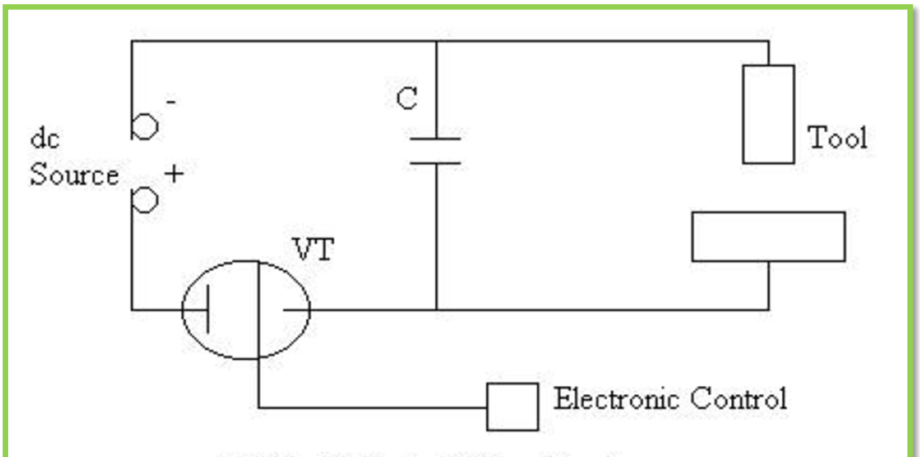
- A framework to define and measure the electrical parameters during an EDM operation directly on inter-electrode volume with an oscilloscope external to the machine has been recently proposed by Ferri *et al.*This would enable the user to estimate directly the electrical parameter that affect their operations without relying upon machine manufacturer's claims.

- When machining different materials in the same setup conditions, the actual electrical parameters are significantly different.When using RC generators, the voltage pulses, shown in Fig. are responsible for material removal.A series of voltage pulses (Fig.) of magnitude about 20 to 120 V and frequency on the order of 5 kHz is applied between the two electrodes.

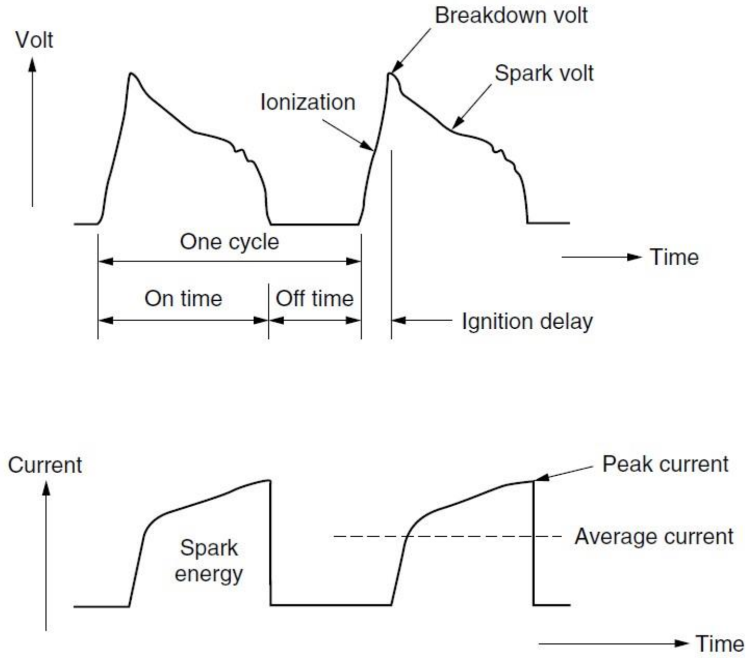
Periodic discharges in RC-type generator.



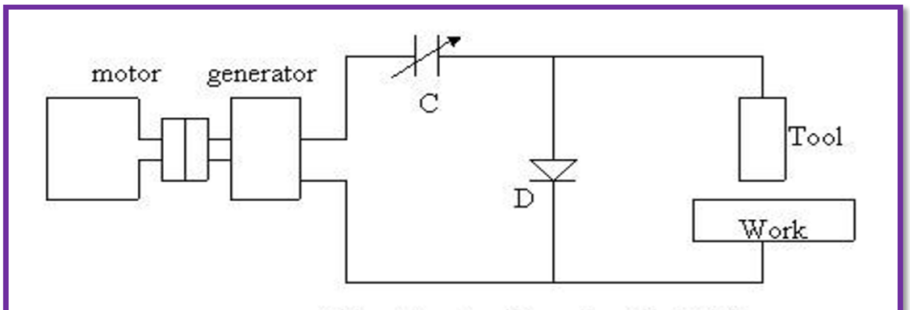
Typical EDM pulse current train for controlled pulse generator.



EDM with Control Pulse Circuit



Voltage and current waveforms during EDM.



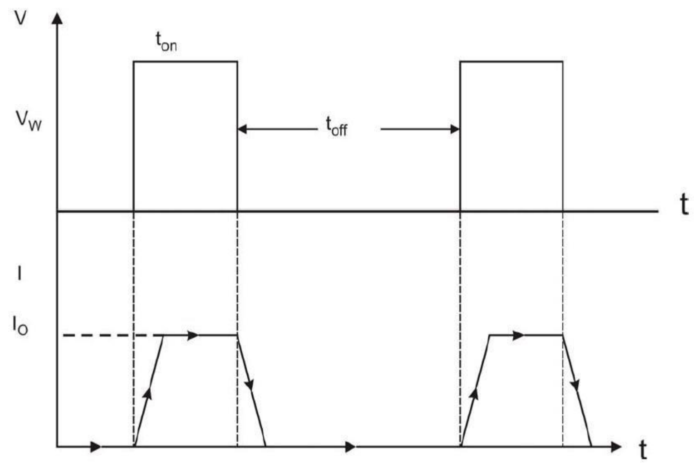
Rotary Impulse Generator for EDM

- Rotary Impulse Generator: MRR is not high in case of RC relaxation circuit. To increase MRR impulse generator is used.
- The capacitor C is charged through the diode during the first half of the cycle and during the following half the sum of the voltages generated by the generator and the charged capacitor is applied to the work – tool gap.
- The operating frequency is the sine wave frequency that depends on motor speed. Though the MRR is higher surface finish is not good.

Process parameters, characteristics, advantages, limitationsand applications of the EDM process.

The process parameters - mainly related to the waveform characteristics
EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive.
The waveform is characterized by the

- The open circuit voltage - Vo
- The working voltage - Vw
- The maximum current – Io
- The pulse on time – the duration for which the voltage pulse is applied – ton
- The pulse off time – toff
- The gap between the work piece and the tool – spark gap – δ
- The polarity – straight polarity – tool (-ve)
- The dielectric medium
- External flushing through the spark gap.



CHARACTERISTICS OF EDM :

- The process can be used to machine any work material if it is electrically conductive
- Material removal depends on mainly thermal properties of the work material rather than its strength, hardness etc
- In EDM there is a physical tool and geometry of the tool is the positive impression of the hole or geometric feature machined
- The tool has to be electrically conductive as well. The tool wear once again depends on the thermal properties of the tool material

- Though the local temperature rise is rather high, still due to very small pulse on time, there is not enough time for the heat to diffuse and thus almost no increase in bulk temperature takes place. Thus the heat affected zone is limited to 2 – 4 μm of the spark crater
- However rapid heating and cooling and local high temperature leads to surface hardening which may be desirable in some applications
- Though there is a possibility of taper cut and overcut in EDM, they can be controlled and compensated.

Advantages of EDM:

1. The process can be applied to all conducting metals and alloys irrespective of their melting points, hardness,
toughness or brittleness.
2. Any complicated shape that can be made on the tool can be reproduced on the work piece.
3. Machining time is less compared to conventional machining.
4. No mechanical stress is present in the process. Physical contact between the tool and work piece is eliminated.
Fragile and slender work pieces can be machined without distortion.
5. Hard and corrosion resistant surfaces essentially needed for die making can be developed.
6. Cratering type of surface finish automatically creates accommodation for lubricants causing the die life to improve.

Disadvantages:

1. Profile machining of complicated contours is not possible at required tolerances.
2. Machining time is slow
3. Machining heats the work piece and hence causes changes in surface and metallurgical properties.
4. Excessive tool wear.
5. High specific power consumption.

Typical EDM applications:

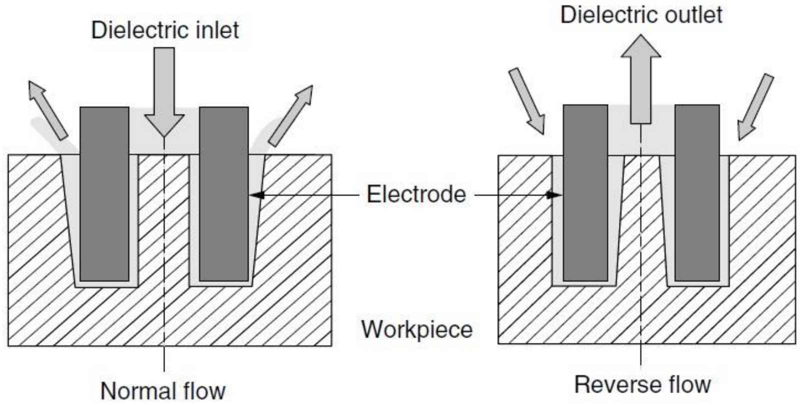
- Fine cutting with thread shaped electrode.
- Drilling of micro holes.
- Thread cutting.
- Helical Profile Milling.
- Rotary Forming.
- Curved hole drilling.

Flushing techniques in detail on EDM process.

- One of the important factors in a successful EDM operation is the removal of debris (chips) from the working gap.
- Flushing these particles out of the working gap is very important, to prevent them from forming bridges that cause short circuits.

- EDMs have a built-in power adaptive control system that increases the pulse spacing as soon as this happens and reduces or shuts off the power supply.
- Flushing – process of introducing clean filtered dielectric fluid into spark gap.
  If flushing is applied incorrectly, it can result in erratic cutting and poor machining conditions.
- Flushing of dielectric plays a major role in the maintenance of stable machining and the achievement of close tolerance and high surface quality.
- Inadequate flushing can result in arcing, decreased electrode life, and increased production time.
- Four methods:

1. Normal flow 2. Reverse flow
3. Jet flushing 4. Immersion flushing



- **Normal flow (Majority)**

  - Dielectric is introduced, under pressure, through one or more passages in the tool and is forced to flow through the gap between tool and work.
  - Flushing holes are generally placed in areas where the cuts are deepest.
  - Normal flow is sometimes undesirable because it produces a tapered opening in the workpiece.

- **Reverse flow**

  - Particularly useful in machining deep cavity dies, where the taper produced using the normal flow mode can be reduced.
  - The gap is submerged in filtered dielectric, and instead of pressure being applied at the source a vacuum is used.
  - With clean fluid flowing between the workpiece and the tool, there is no side sparking and, therefore, no taper is produced.

- **Jet flushing**

  - In many instances, the desired machining can be achieved by using a spray or jet of fluid directed against the machining gap.
  - Machining time is always longer with jet flushing than with the normal and reverse flow modes.

- **Immersion flushing**

  - For many shallow cuts or perforations of thin sections, simple immersion of the discharge gap is sufficient.
  - Cooling and debris removal can be enhanced during immersion cutting by providing relative motion between the tool and workpiece.
  - Vibration or cycle interruption comprises periodic reciprocation of the tool relative to the workpiece to effect a pumping action of the dielectric.
  - Synchronized, pulsed flushing is also available on some machines.
  - With this method, flushing occurs only during the non-machining time as the electrode is retracted slightly to enlarge the gap.
  - Increased electrode life has been reported with this system.
  - Innovative techniques such as ultrasonic vibrations coupled with mechanical pulse EDM, jet flushing with sweeping nozzles, and electrode pulsing are investigated by Masuzawa (1990).

- For proper flushing conditions, Metals Handbook (1989) recommends:

  - Flushing through the tool is more preferred than side flushing.
  - Many small flushing holes are better than a few large ones.
  - Steady dielectric flow on the entire workpiece-electrode interface is desirable.
  - Dead spots created by pressure flushing, from opposite sides of the workpiece, should be avoided.
  - A vent hole should be provided for any upwardly concave part of the tool-electrode to prevent accumulation of explosive gases.
  - A flush box is useful if there is a hole in the cavity.