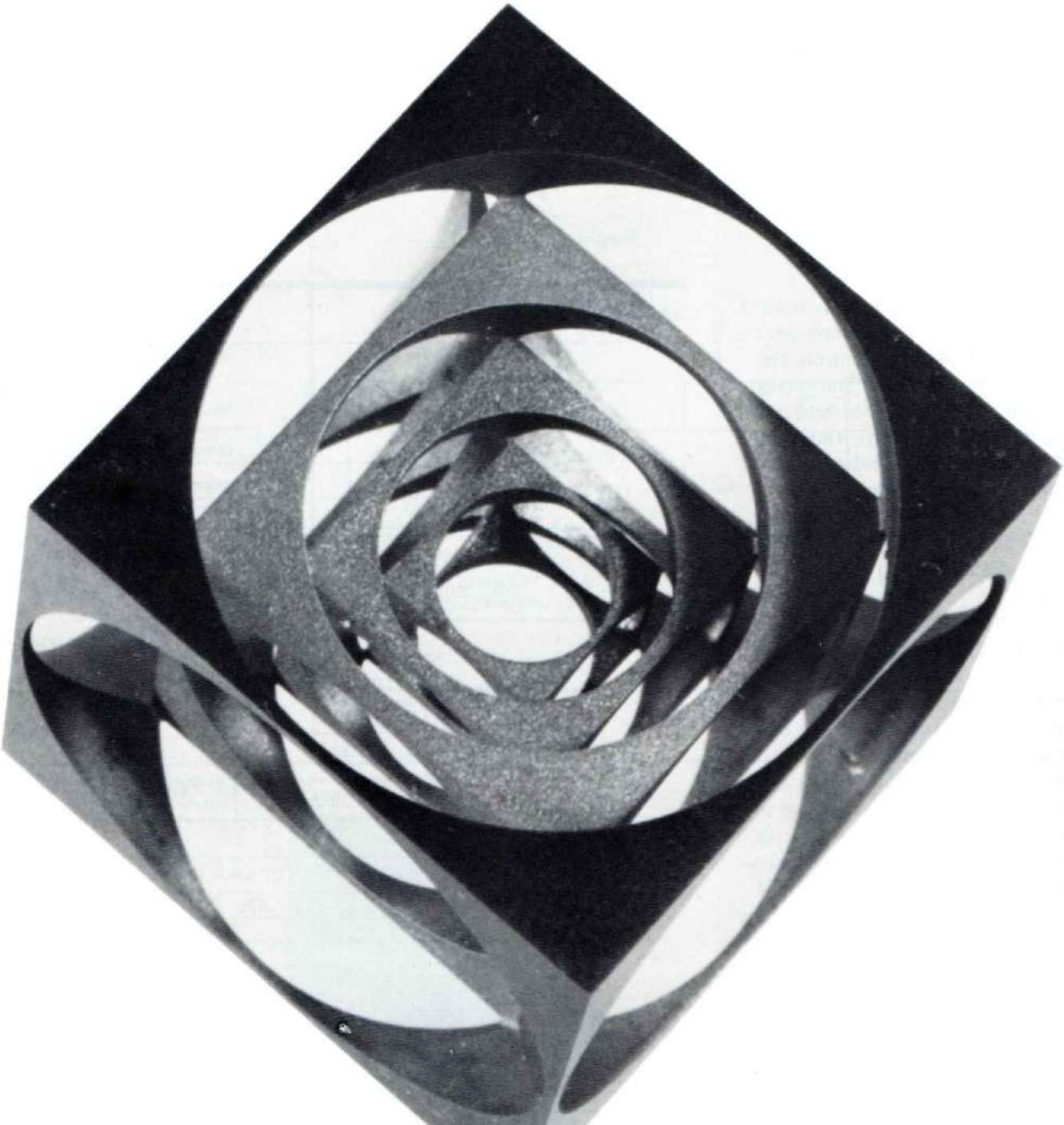


This carbide cube, submitted by Ing. Jan Wiejers and Ing. C. V. Osbruggen, has been EDM'd to specific tolerances as a training project by apprentices at the N. V. Philips Research Laboratory in Eindhoven (WZ) Netherlands. The test being—any misalignment will cut one of the corners of the cube, resulting in vibration of the loose part that totally disrupts the EDM'ing process. See the following pages for their informative approach to EDM'ing with Micro-Precision.

EDMing with Micro-Precision

by Jan L. C. Wijers and C. V. Osenbruggen

Electrical Discharge Machining as a machining technique is at this very moment accepted world-wide for the production of relatively small products soaring up into a range of dimensions as big as side panels of automobiles.

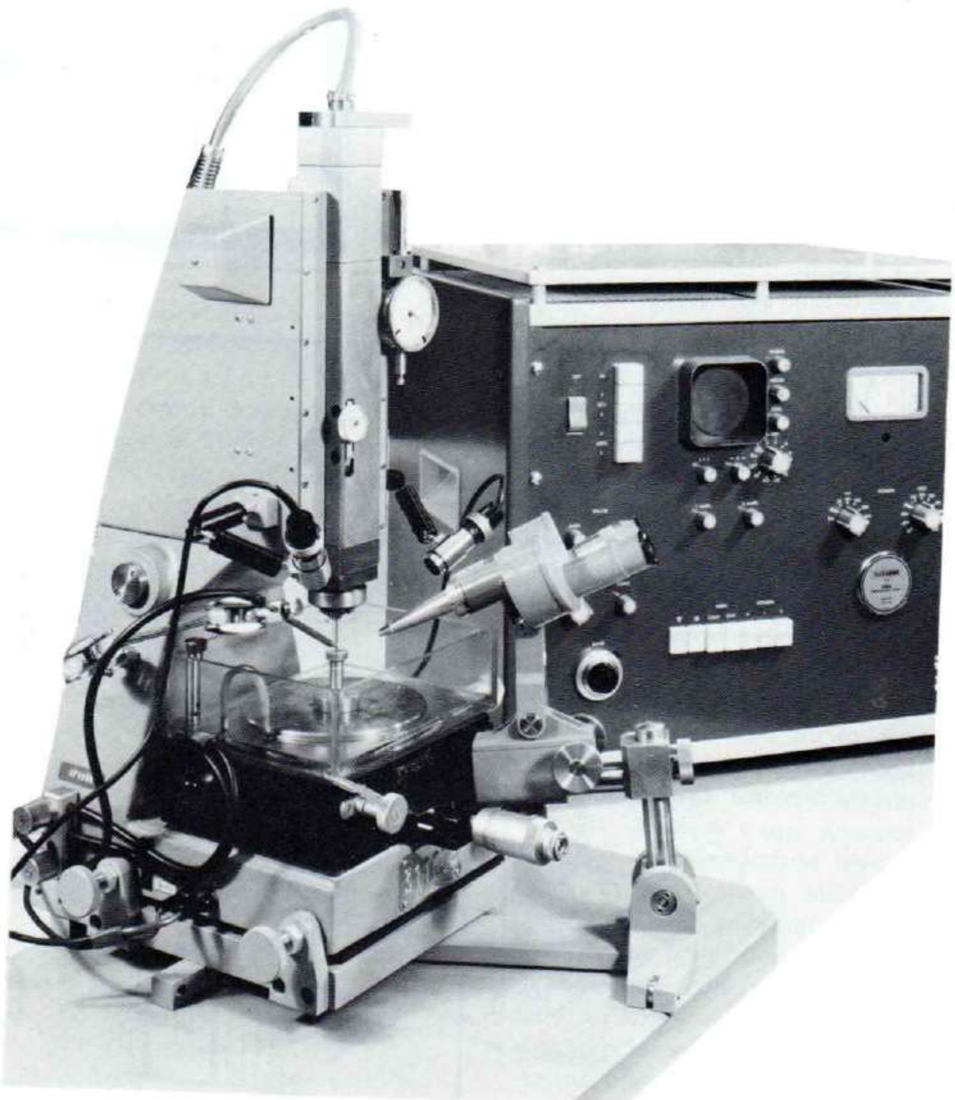
However, EDMing in the micro-region is gaining acceptance now.

Inspired by requests from several NV. Philips production departments; late in the 60's, a systematic approach was launched into the development of EDM-systems capable of very accurate and rapid machining of holes and profiles of very small dimensions.

EDM promised to offer a way out of the production problems encountered with conventionally machining very hard conductive materials within this region.

Conventional machining processes such as turning, milling and grinding are more or less characterized by the fact that the tool is inevitably the hardest and the toughest in the mechanical struggle (between tool and workpiece) in which both are in direct physical contact during machining.

On the other hand Electrical Discharge Machining (fig. 1) is based on an electro-thermal machining process. Since there should be no mechanical contact between the electrode and the workpiece while EDMing this process is totally independent of the hardness ratio of electrode material to the workpiece material.



Photograph 1: Philips Micro EDM Machine

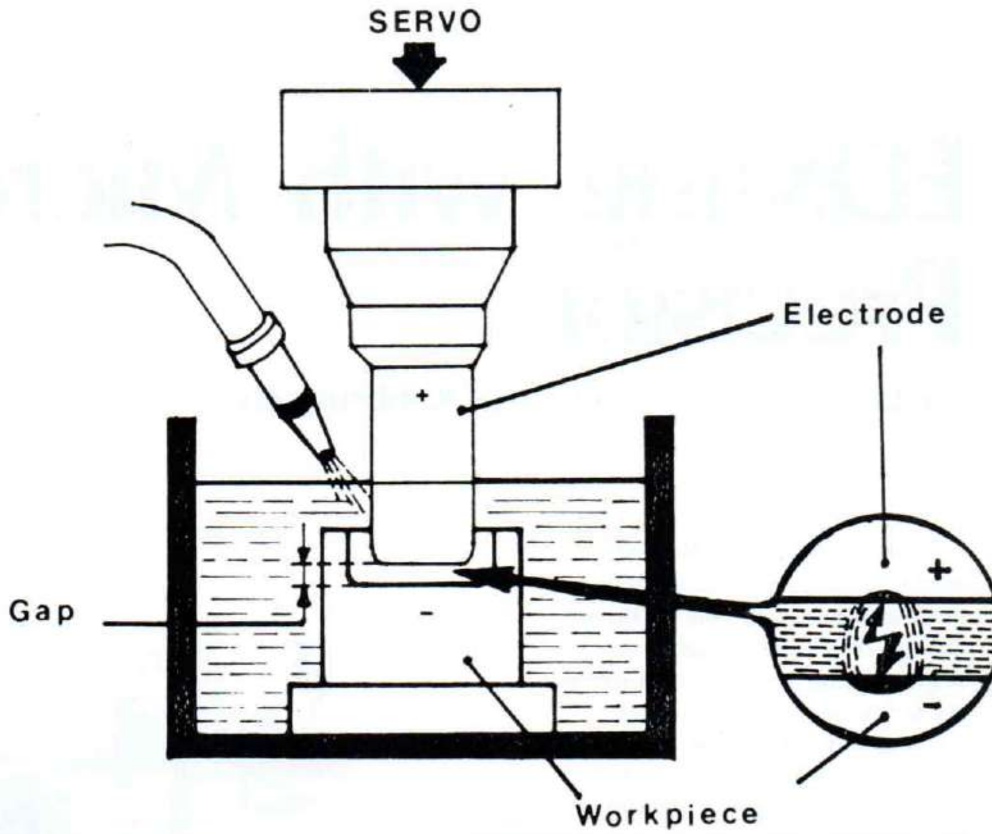


Figure 1: The principle of EDM: An electrode and a conductive workpiece are held a short distance apart, the spark gap between them being filled with the dielectric fluid. If the distance between two points on either side of the gap is small enough, a voltage pulse applied between the electrode and the work will result in a spark discharge, causing material to be removed. A special mechanism ensures that the spark distance is held constant by advancing the electrode. Particles removed by sparking have to be flushed away.

A characteristic feature of EDM is that all electrical conductors and non-conductors with a conductive surface coating (in some cases formed during the EDM process) can be machined irrespective of their mechanical properties. The EDM technique allows for the advantages previously mentioned and furthermore brings larger L/D (Length over Diameter) ratio's into view. Despite the lack of sophistication of the power supplies during EDM's infancy the EDM *"sinking"* process prevailed; that is, sinking an electrode into a workpiece along a straight vertical line (the Z-axis of the EDM system), i.e., straight-sinking, threading, 3-D die sinking operations both blind and through (fig. 1B). Workshops world-wide are now able to produce exterior *'open'* profiles and workpieces of great accuracy of form, dimension and surface quality. As long as the profile is open to conventional tools, this statement stands.

However the interior profiles do introduce the first strands of gray hair.

Here EDM-sinking comes in, first of all as a beautiful and handy way to bypass the obstacles encountered in producing internal ('closed') profiles.

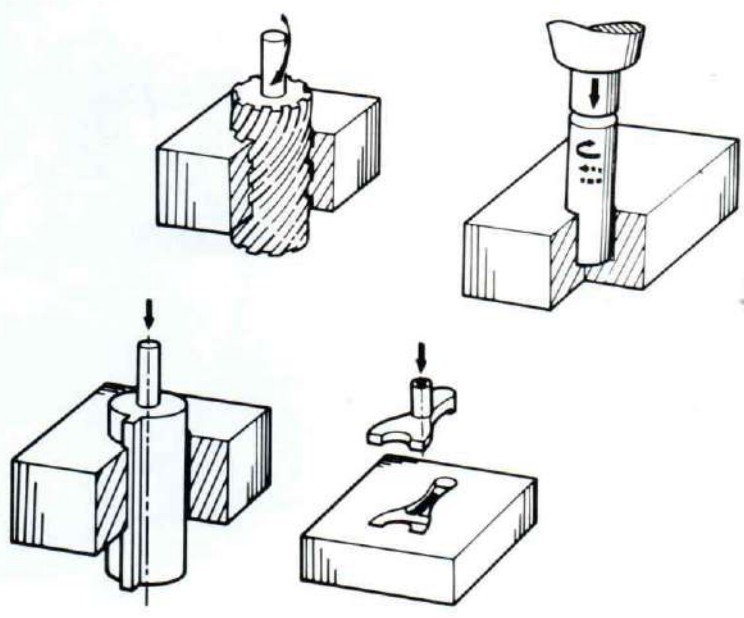


Figure 1B

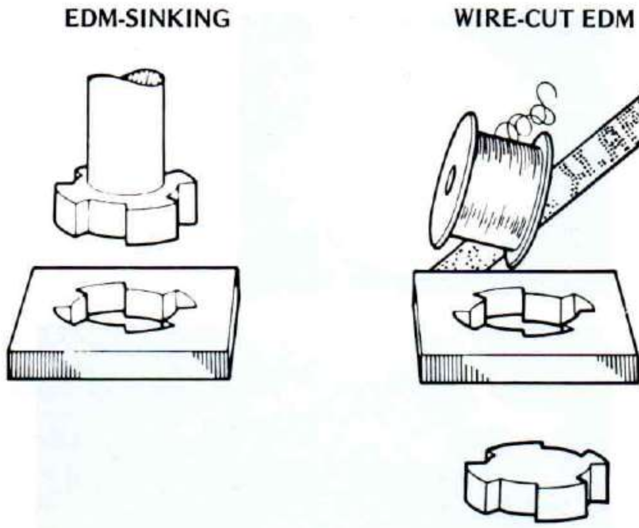


Figure 2

It converts the machining of a difficult interior form in a predominantly hard workpiece-material into first producing an electrode (possessing an exterior or positive profile) out of a softer, easier machinable material. This tool electrode is then used as the intermediate to reproduce ('copy') the profile in the EDM sinking mode (fig. 2).

On the other hand the unequalled success of Wire-EDM, later in the 70's and 80's, can be furthermore attributed to the fact that the profile is now erosively generated, not copied!

When wire EDMing, pre-produced electrodes are eliminated by the combination of a constantly self renewing wire-electrode with numerical control (NC) or computor numeral control, CNC systems.

Out of the information the NC-system obtains from the punched tape or binary data fed into the CNC-unit, the workpiece is cut-out erosively, similar to fret-sawing.

Opposed to EDM-sinking in this manner it is not necessary to machine the full cubic content of the profile. Only the length of the profile-path times the wire diameter plus 2 Gap times the height of the workpiece is to be removed by EDM-ing (fig. 2B).

$$V = L \times (d + 2G) \times H$$

The original drawbacks as to the application of EDMing were the relatively low rate of machining and the high wear of the tool electrode (the ratio between the amounts of material removed from the two electrodes depends mainly on the amount of energy dissipated in each of them). These difficulties were later overcome by improvements in the power supply to control the power and frequency of the electrical discharges and by using special electrode materials.

Machining to high accuracies (fig. 3) demands a very careful choice of the conditions in which the EDM process is carried out. The electrode must be accurately shaped and an intricate control mechanism will be employed to maintain the narrow spark gap of about $2-3\ \mu m$. Also the EDM'd particles have to be smaller to facilitate their removal from the spark gap area to prevent causing a shortcircuit. Moreover, the smoothness required of the machined surface sets a limit to the dimensions of the craters formed while sparking. Our investigations have shown that for these reasons low-energy, high-frequency discharges have to be used for precise EDMing, with a discharge ('ON') time which is so short that only the SPARK stage of the discharge is utilized, the ARC stage following is generally being suppressed (fig. 3B).

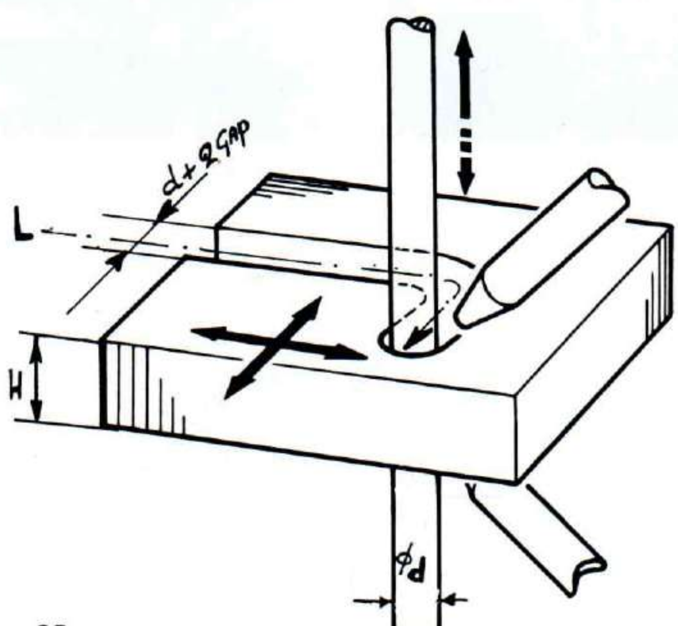


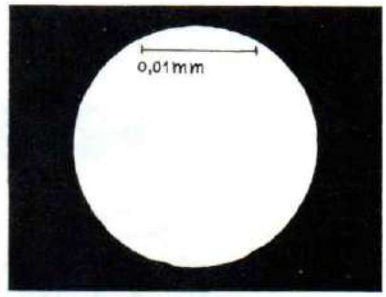
Figure 2B

While energies ranging from 0.0003 to 2.0 J and discharge times of 1 to 2000 μ s are customary for normal EDM operations, the energy required for high-precision spark machining is about 10^{-8} J and the discharge time about 0.03 μ s. Despite the large differences in discharge energy and discharge time, it has been found possible to attain an efficiency (in terms of quantity of material removed per unit of energy) which is just as high as that of normal EDMing, while electrode wear can also be kept within very acceptable limits.

The rate of machining is a rather different matter. It might appear difficult to perform a given operation quickly and maintain a relatively high EDMing efficiency, since in high-precision EDMing only a very small quantity of material is removed by each discharge.

However, a relatively high machining rate can be attained by employing a high repetition rate. This means that certain special requirements also have to be met in generating discharges.

Figure 3



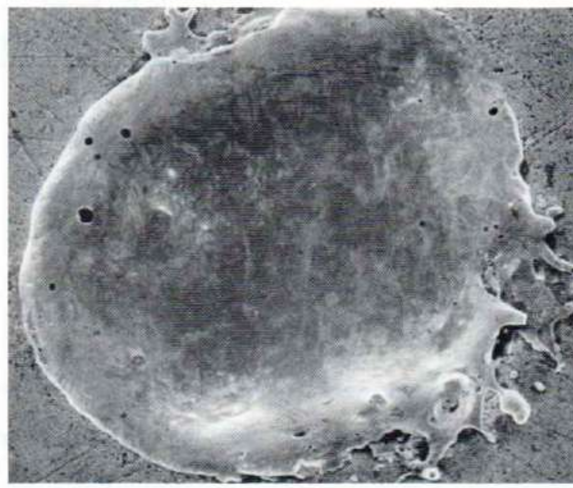


Figure 3B: Single Discharge in Tungsten Carbine

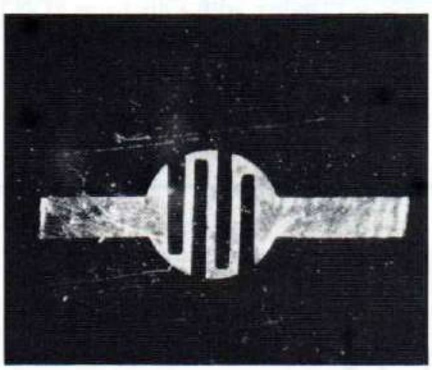
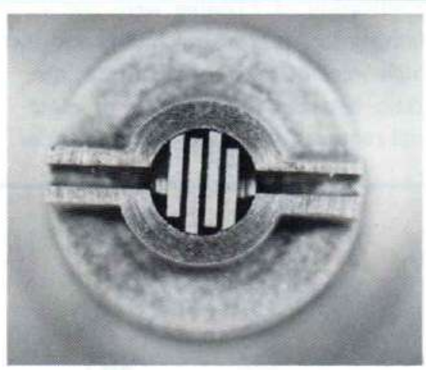
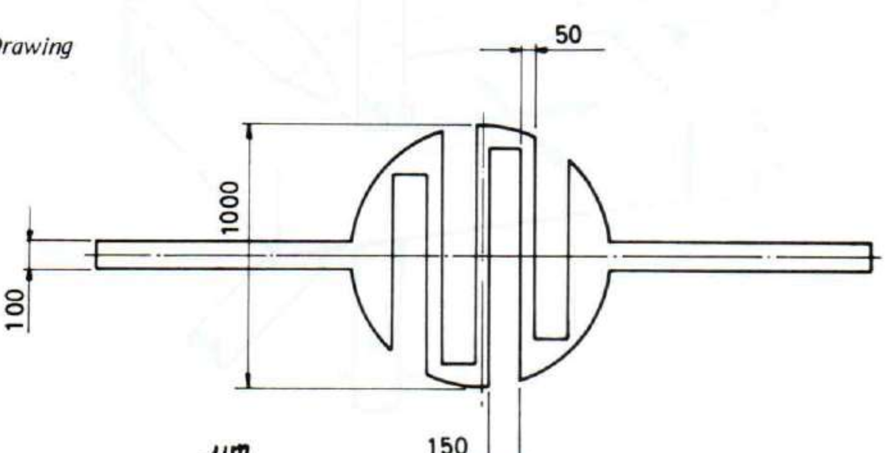


Figure 4: Workpiece



Electrode System

Drawing



The repetition rate has an upper limit which is determined by the speed with which the original deionized situation is restored after the ionization during breakdown (depending on the kind of dielectric used) and by the speed with which impurities such as eroded particles and the decomposition products of the dielectric fluid can be removed, e.g., by forced circulation of the liquid through a filter. During the process the spark gap must be flushed thoroughly. The reason for this is that the presence of conducting particles affects the breakdown field strength of the dielectric and also causes discharges at the wrong places, so that the eroded cross-section becomes tapered. On the other hand a certain amount of contamination by very small particles (smaller than 0.01 μ m) is necessary to obtain a rapid formation of the spark once the breakdown voltage has been reached.

A relatively heavy hydrocarbon is frequently used as the dielectric fluid. The choice of fluid is rather limited, since the dielectric must satisfy a