10.3.1.2 Electrical arcs

An *electrical arc* is a self-sustaining electrical discharge between at least two electrodes and is characterized by a comparatively small *cathode fall voltage*, a low *burning voltage* and a relatively high *current density*. The burning voltage of an arc is the voltage across the *electrode gap* during an arc discharge.

Based on the operating current, one has the *low current arc* (below 10 A), the *medium current arc* (10-30 A) and the *high current arc* (>30 A). For spectrochemical purposes mainly low current and medium current arcs are used. The temperatures of the low and medium current arc plasmas considered in this document range between 3000 and 7000 K according to the *ionization potential* of the elements present.

10.3.1.2.1 Current-carrying arc plasma

A distinction may be made between *free burning arcs* and *stabilized arcs* according to the form of the *current-carrying arc plasma*.

Electrical arcs can be operated either with direct or with alternating current. The plasma can be current-carrying and *non-current-carrying*.

10.3.1.2.2 Free-burning arcs

A *free-burning arc* operates mainly in the surrounding gas and partly in the vapour, which it generates. The plasma of such an arc is formed freely in space. Its shape depends only upon the type and form of the electrode material, the electrode gap, the electrical parameters of the discharge and the chemical composition and convection properties of the discharge gas.

The *direct current arc* (dc arc): The most basic type of electrical arc is the dc arc. The dc arc is fed by a source having a total available voltage of between 100 and 300 V and a power of some kW. A resistor or some other stabilizing device must be used in the circuit of the dc arc to compensate for the *negative voltage-current characteristics*.

The *alternating current arc* (ac arc): The alternating current arc is fed by a mains voltage ac supply. Sometimes voltages of up to some thousands of volts are used. The ac arc can sometimes be operated as a *thermally ignited arc* without external ignition. When no ignition is used, the arc is said to be an *uncontrolled ac arc*. The size of the electrode gap, however, usually necessitates re-ignition of the arc for each half cycle. The *ignition* can be done by a high frequency discharge, also known as an *ignition spark*. When the ignition is triggered electronically, one has an *electronically ignited* or a *controlled ac arc*. Ignition after every half cycle of an applied ac voltage results in an *ignited ac arc*. Ignition at every full cycle results in a *rectified ac arc,* which is a special kind of interrupted dc arc. In the rectified ac arc, only one half cycle of the current phase of the arc flows. The arc must be re-ignited after each phase.

10.3.1.2.3 Stabilized arcs

Temporal and *spatial stabilization* of the arc plasma may lead to an improvement in detection limits and/or precision of measurements (stabilized arc).

Magnetically stabilized arcs. Stabilization may be achieved by the influence of both homogeneous and non-homogeneous magnetic fields.
Gas-stabilized arcs. The arc plasma may be stabilized by a gas stream around the arc which prevents radial wandering of the plasma.

Wall-stabilized arc. (The use of terms such as constricted arcs, etc. are discouraged). Stabilization may be achieved by allowing the arc to burn through one or several orifices in cooled metal or graphite discs or through a cooled silica tube, thus fixing the position of the *arc column*. An arc burning through such a disc or tube is called a wall-stabilized arc. Such wall stabilization constricts the diameter of the plasma, which then has a higher temperature in the constricted part. At high current densities, the magnetic effect of the current may cause a *pinch effect* resulting in a further constriction of the arc column.

10.3.1.2.4 Interrupted arcs

All of the arcs mentioned may be operated as interrupted arcs. The interruption may be done periodically by electrical or mechanical means. The ratio of the burning period to the non-burning period (on-off ratio) is called the *duty cycle*. The number of burning periods per unit time is the *repetition rate* of the interrupted arc.

10.3.1.2.5 Non-current-carrying plasmas

When a dc arc operating between electrodes in an enclosure is blown by a stream of gas from its normal discharge passage through an orifice, a non-current-carrying plasma is produced. The flow of gas may be parallel or perpendicular to the direction of the electrical current. In some configurations, this arc has good temporal and spatial stability. This type of arc is called a *plasma jet*.

10.3.1.2.6 Transferred plasmas

In some configurations of plasma jets, a third electrode may be introduced, so that the plasma is transferred from one of the original electrodes to this third (external) electrode. The resulting *transferred plasma* also has good spatial and temporal stability. A *three-*

electrode plasma generated between two anodes and one cathode belongs to this category.

10.3.1.2.7 Arc atmospheres

An arc may operate in air, or in an atmosphere (*arc atmosphere*) of argon, carbon dioxide or a mixture of gases such as argon and oxygen at atmospheric or other pressures. When a carbon arc burns in air, nitrogen reacts with the carbon to form cyanogen, which emits intense *cyanogen molecular bands*. These bands often mask spectral lines. By choosing a suitable *controlled atmosphere* free of nitrogen, this may be prevented and the arc stability improved. This *shielded electrical discharge* can be achieved by arcing in a relatively large arc chamber producing a free burning arc, or by using a small cuvette with tangential or laminar flow. When the gas emerges as a *laminar sheath* from openings (or a slit) around the lower electrode, it prevents air from reaching the arc, and an arc chamber is thus not required.