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Standard Practice for Describing Photomultiplier Detectors in Emission and Absorption Spectrometry[1]

This standard is issued under the fixed designation E 520; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers photomultiplier properties that are essential to their judicious selection and use of photomultipliers in emission and absorption spectrometry. Descriptions of these properties can be found in the following sections:

1.2 Radiation in the frequency range common to analytical emission and absorption spectrometry is detected by photomultipliers presently to the exclusion of most other transducers. Detection limits, analytical sensitivity, and accuracy depend on the characteristics of these current-amplifying detectors as well as other factors in the system.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 135 Terminology Relating to Analytical Chemistry for Metals, Ores, and Related Materials

3. Terminology

3.1 *Definitions*—For terminology relating to detectors refer to Terminology E 135.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *solar blind*, *n*—photocathode of photomultiplier tube does not respond to wavelengths on the high side.

3.2.1.1 *Discussion*—In general, solar blind photomultiplier tubes used in ~~optical~~atomic emission ~~spectroscopy~~spectrometry transmit radiation below about 300 nm and do not transmit wavelengths above 300 nm.

4. Structural Features

4.1 *General*—The external structure and dimensions, as well as the internal structure and electrical properties, can be significant in the selection of a photomultiplier.

[1] This practice is under the jurisdiction of ASTM Committee E01 on Analytical Chemistry for Metals, ~~Ores,~~Ores and Related Materials and is the direct responsibility of Subcommittee E01.20 on Fundamental Practices.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* ~~, Vol 03.05.~~volume information, refer to the standard's Document Summary page on the ASTM website.

4.2 *External Structure*—The external structure consists of envelope configurations, window materials, electrical contacts through the glass-wall envelopes, and exterior housing.

4.2.1 *Envelope Configurations*—Glass envelope shapes and dimensions are available in an abundant variety. At present, two envelope configurations are common, the end-on (or head-on) and side-on types (see Fig. 1).

4.2.2 *Window Materials*—Various window materials, such as glass, quartz and quartz-like materials, sapphire, magnesium fluoride, and cleaved lithium fluoride, cover the ranges of spectral transmission essential to efficient detection in spectrometric applications. Window cross sections for the end-on type photomultipliers include plano-plano, plano-concave, convexo-concave forms, and a hemispherical form for the collection of 2-π radians of light flux.

4.2.3 *Electrical Connections*—Standard pin bases, flying-leads, or potted pin bases are available to facilitate the location of a photomultiplier, or for the use of a photomultiplier at low temperatures. TFE-fluorocarbon receptacles for pin-base types are recommended to minimize the current leakage between pins.

4.2.4 *Housing*—The housing for a photomultiplier should be "light tight." Light leaks into a housing or monochromator from fluorescent lamps are particularly bad noise sources which can be readily detected with an oscilloscope adjusted for twice the power line frequency. A mu-metal housing or shield is recommended to diminish stray magnetic field interferences with the internal focus on electron trajectories between tube elements.

4.3 *Internal Structure*—The internal structure consists of arrangements of cathode, dynodes, and anodes.

4.3.1 *Photocathode*—A typical photomultiplier of the end-on configuration possesses a semitransparent to opaque layer of photoemissive material that is deposited on the inner surface of the window segment in an evacuated glass envelope. In the side-on window types, the cathode layer is on a reflective substrate within the evacuated tube or on the inner surface of the window.

4.3.2 *Dynodes and Anode*—Secondary-electron multiplication systems are designed so that the electrons strike a dynode at a region where the electric field is directed away from the surface and toward the next dynode. Six of these configurations are shown in Fig. 2. Ordinarily a photomultiplier uses from 4 dynodes to 16 dynodes. There are several different configurations of anodes including multianodes and cross wire anodes for position sensitivity.

4.3.3 *Rigidness of Structural Components*— The standard structural components generally will not endure exceptional mechanical shocks. However, specifically constructed photomultipliers (ruggedized) that are resistant to damage by mechanical shock and stress are available for special applications, such as geophysical uses or in mobile laboratories.

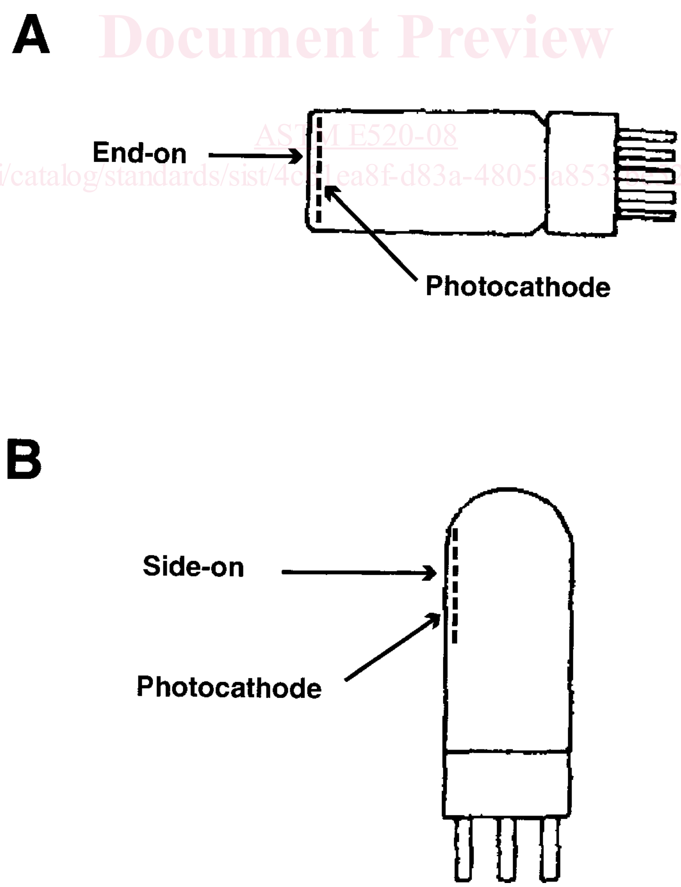

FIG. 1 Envelope Configurations

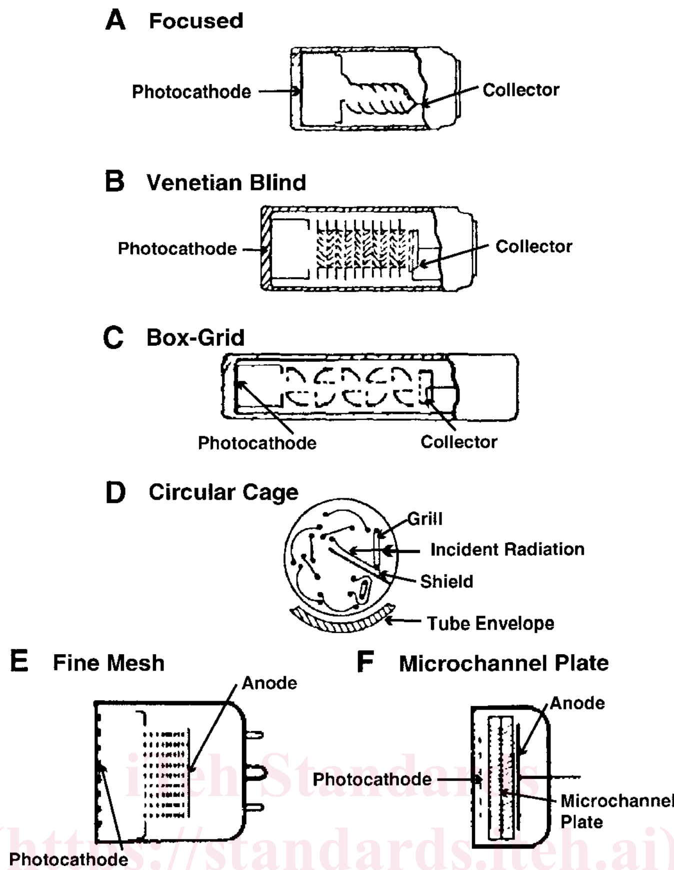

FIG. 2 Electrostatic Dynode Structures

5. Electrical Properties

5.1 *General*—The electrical properties of a photomultiplier are a complex function of the cathode, dynodes, and the voltage divider bridge used for gain control.

5.2 *Optical-Electronic Characteristics of the Photocathode* —Electrons are ejected into a vacuum from the conduction bands of semiconducting or conducting materials if the surface of the material is exposed to electromagnetic radiation having a photon energy higher than that required by the photoelectric work-function threshold. The number of electrons emitted per incident photon, that is, the quantum efficiency, is likely to be less than unity and typically less than 0.3.

5.2.1 *Spectral Response*—The spectral response of a photocathode is the relative rate of photoelectron production as a function of the wavelength of the incident radiation of constant flux density and solid angle. Spectral response is measured at the cathode with a simple anode or at the anode of a secondary-electron photomultiplier. Usually, this wavelength-dependent response is expressed in amperes per watt at anode.

5.2.1.1 Spectral response curves for several common standard cathode-types are shown in Fig. 3. The S-number is a standard industrial reference number for a given cathode type and spectral response. Some of the common cathode surface compositions are listed below. Semiconductive photocathodes, for example, GaAs(Cs) and InGaAs(Cs), as well as red-enhanced multialkali photocathodes (S-25) are also available. A "solar blind" response cathode of CsI, not shown in Fig. 3, provides a low-noise signal in the 160-nm to 300-nm region of the spectrum. Intensity measurements at wavelengths below 100 nm can be made with a windowless, gold-cathode photomultiplier.

Examples of Cathode Surfaces

Response Type Designation	Window	Cathode Surface
S-1	Lime Glass	Ag-O-Cs (Reflection)
S-5	Ultraviolet Transmitting Glass	Sb-Cs (Reflection)
S-11	Lime Glass	Sb-Cs (Semitransparent)
S-13	Fused Silica	Sb-Cs (Semitransparent)
S-20	Lime Glass	Sb-Na-K-Cs (Semitransparent)

5.3 *Current Amplification*—The feeble photoelectron current generated at the cathode is increased to a conveniently measurable level by a secondary electron multiplication system. The mechanism for electron multiplication simply depends on the principle