8.2 – Sensors

> **Back to main index** < > **Go to the sensor index** <

The tube collection includes several sensors designed for applications in some kinds of physics measurements or detection.

8.2.1 – Displacement, vibration sensors

Some tubes were devised to sense or measure mechanical quantities, position, acceleration or even vibrations, interacting with electrodes. The twin diode 6MX1C sensor uses a sensing rod which transmits displacements to the two anodes through a flexible diaphragm, moving their position with respect to the fixed common cathode. This tube is similar as per electrode structure to the Ramberg accelerometer described in Electronics, where the twin-anode system was connected to a mass elastically suspended in the glass bulb. In the RCA 5734 'Vibrotron', the rod terminates inside the envelope, through a flexible diaphragm, to form the anode of a triode. Any mechanical displacement of the sensing tip changes the relative position of electrodes and hence the transconductance. Due to the very low mass of the anode system, 5734 was usable up to 12 kHz.

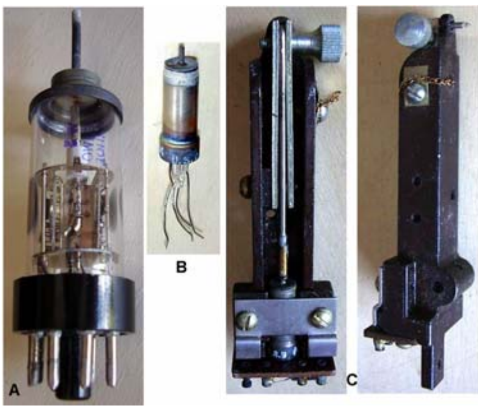

Fig. 8.2.1 - Mechanical displacement sensors. A) In the Russian 6MX1C the plates of two internal diodes are supported by the rod protruding from the top, through a flexible diaphragm. B) The RCA 5734 is a triode in which the plate is the internal extension of the sensing tip. C) Two views of a pick-up using the 5734 as active transducer, bottom in the left image. Not sure what the above pick-up was intended for.

8.2.2 – Magnetic field sensors

Here we find tubes designed to operate as magnetic sensors or even as switches activated by magnetic fields. In some of them operating principles resemble the operation of a magnetron, electrons being forced by the magnetic field to follow more and more curved trajectories, up to the cutoff. Usually they are diodes with cylindrical structure and filamentary or unipotential cathode. Some were designed for use into physics laboratories to demonstrate the Hull effect.

Other kind of magnetic sensors were devised in the years. In the fifties National Union, one of the most active firms in non-conventional tubes, designed a kind of electronic magnetic pick-up to replace the play head in magnetic tape recorders. Another sensor introduced by RCA in the thirties is a sort of CRT, cathode ray tube, which allows to investigate directions of flux lines of a magnetic field. In this case electrons are generated by an electron gun protruding from the center of an anode dish. The beam is deflected some 180 degrees to impinge anode and striking point position moves according to the external magnetic fieds. The trace is made visible by a small amount of noble gas.

Fig. 8.2.2 - Magnetic field sensors. A) The British Ferranti GRD7 was a cylindrical diode intended for educational and demo purposes, including the Hull magnetron effect. B) General Electric 2B23 was a diode controlled by external magnetic fields. It could operate as linear sensor or as switch. C) This magnetic probe was a special CRT, electrons being emitted upwards, with a little inclination, from the center of the plate dish. The beam is then deflected by the electrostatic field to turn some 180 degrees and hit the plate halfway between the center and the edge of the plate itself, to form a sort of visible hook. Any superimposed magnetic field deflects the beam and instantly changes the trajectory of the beam.

8.2.3 – Mass sensors

Here we find a single device, a sensor for mass-spectrography. Small samples of the material to analyze is introduced in a vacuum chamber connected to the sensor. Ions are accelerated by electric orthogonal fields. Their deflection varies with mass.

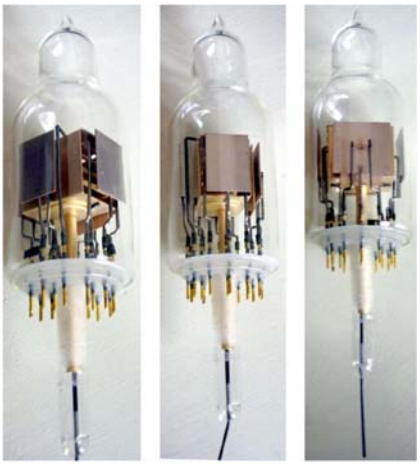

Fig. 8.2.3 - Sample of Philips custom Omegatron. To be cleaned at high-temperature before use, electrodes are made of iridium or osmium. The bulb of this sample is still sealed.

8.2.4A – Radiation, nuclear

Nuclear detectors include both radiation and particle sensors. In this section we only find complete sensors devices as Geiger counters and scintillators. Photomultipliers, even if widely used in radiation sensors to detect radiation from scintillators, are listed in a different section. In Geiger counters a low-pressure gas is biased near to its ionization threshold. Radiation from outside ionizes the gas causing a sudden discharge which is readily quenched by a quenching media. The count of discharges is proportional to the ionizing particles that pass through the sensor in the time unit.

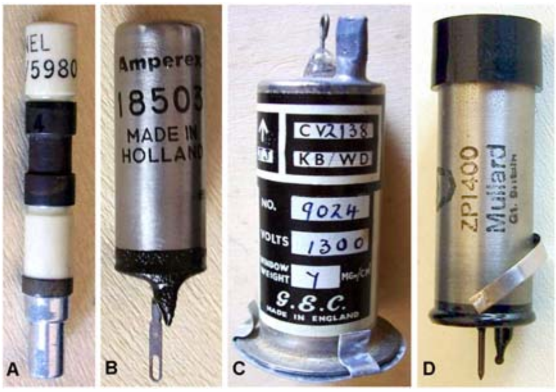

Fig. 8.2.4 - Geiger counter tubes. A) A Lionel 5980 cartridge sensor. B) Actually this Amperex badged 18503 was made by Philips. D) A British GEC CV2138 Geiger counter. D) ZP1400 was another beta and gamma radiation counter by Philips and related companies.

8.2.4B – Radiation RF

Since the early experiments with radio waves, either filamentary lamps and neon bulbs were used as detectors of RF fields. Some families of specialized RF detectors were then introduced in the years, including indicators, for visual evaluation of RF power, and sensors, to convert RF fields in electrical values as resistances or voltages. We find thermocouples, bolometers, incandescent lamps, sometimes usable as bolometers and neon indicators.

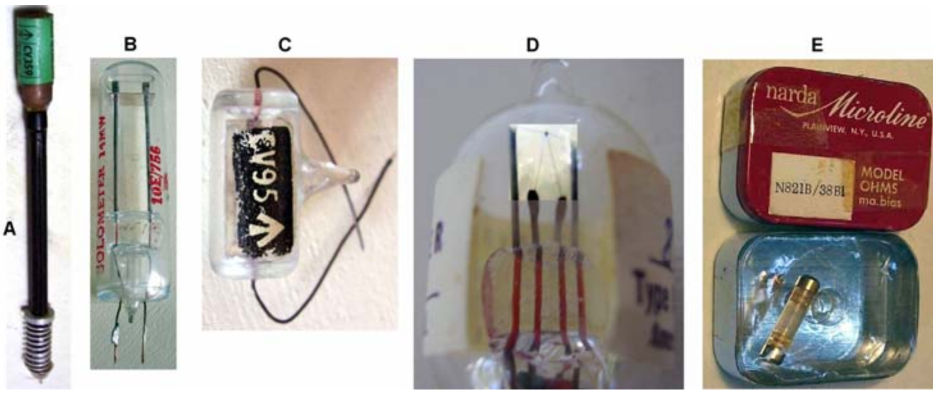

Fig. 8.2.5 - Some radio frequency sensors. A) CV359 was a neon indicator designed to operate inside S-band waveguides with RF peak power up to 200 kW. B) 10E/756 is a British bolometer approved as CV984. The resistive element is mounted close to the top surface in a recess formed in the glass. C) CV95 was a GEC sensitive bolometer. D) A 4-wire thermocouple can be used to sense the RF current flowing in the heating resistor by measuring the voltage across the thermocouple leads. D) Narda N821B was a cartridge type bolometer to be mounted in a coaxial mounting.

8.2.4C – Radiation sensors, visible, IR, UV

Here we find several devices sensitive to IR, visible or UV, ranging from simple photocells, to photoresistors and photomultipliers, used to detect even the smallest radiations. Even imaging tubes, as vidicon and orthicon tubes, or image converters, are listed in this section.

Photoresistors are made by materials whose resistance is inversely proportional to the light incident on its surface, usually cadmium sulphide, CdS. Depending upon the type and size the resistance could vary from megaohms in the dark to tens or hundreds of ohms in full light. For their properties photoresistors could directly drive DC or even AC loads, such as relay coils.

Photocells are cold-cathode electron tubes in which emission is caused by the light incident on a photocathode. Here a surface coated with caesium in combination with other materials, as silver or antimony, is capable of emitting electrons when illuminated. Depending upon the sensitive coating, photocells have their sensitivity peak from infrared through visible up to UV spectrum. Emission is quite low, in the order of microamperes.

Fig. 8.2.6 - Samples of photoresistors and of photocells. A) Raytheon-ELSI [EM-1052] was a small cadmium-selenide photoresistor useful in industrial controls. B) [7427] was proposed to control street lights. It was capable of directly energizing the coil of a relay. C) Philips [ORP30] was a large area cadmium sulphide photoresistor capable of driving the coil of a relay. D) 868 high-sensitivity gas-filled phototube was used in industrial controls. E) 930 was a gas-filled phototube with IR peak sensitivity. F) British CMG22 was used for reading sound tracks.

The basic emission principle of photocells is also used in photomultipliers. Here the feeble current originated by the photocathode is amplified by secondary emission in a cascaded structure of electrodes, called dynodes, which acts both as anode or collectors for electrons coming from the previous stage and as cathode for the next stage.

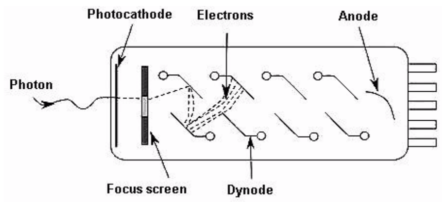

Fig. 8.2.7 - Internal structure of a photomultiplier. Electrons emitted by the photocathode are attracted by the upper first dynode, By secondary emission electrons are multiplied at each impact on a dynode, so that plenty of electrons reach the anode after the travel through eight, or more, cascaded dynode stages.

Fig. 8.2.8 - Samples of photomultiplier tubes. A) [1P28], introduced in 1944, was a 9 stage photomultipler sensible to UV radiation. [150AVP] was a 9-stage, linear focusing pm with peak sensitivity in the blue. C) [931A] was introduced in 1941, probably the first commercial pm. Among its countless applications there is an early optical character reader in 1955. D) A DuMont [6364] 5-inch, 10-stage pm. E) Thorn-EMI [9765K] is characterized for its venetian blind dynode structure. F) [C31007G13] was an experimental RCA PM with a circular cage type dynode structure.

8.2.5 – Vacuum sensors

Many tube manufacturers also listed high vacuum sensors, offering the same devices they designed for internal use in their own plants. We find several operating principles, depending upon the magnitude of the vacuum to measure: thermocouples, temperature-sensitive resistors or Pirani sensors, high-sensitivity hot-cathode ionization gauges and even cold-cathode types. Generally at very low pressure vacuum is measured by monitoring the quantity of ions in the rarefied gas. Sensors were usually designed to be cleaned and degassed at high temperature. Usually bulbs were hard glass, such as Pyrex or Nonex. Electrodes were supported by glass arbors, to avoid use of mica spacers. Base was usually missing in sensors intended for high-temperature cleaning.

Pirani sensors are based upon a temperature-sensitive filamentary resistor in which a small amount of current flows. Filament temperature, and hence its resistance, depends upon the convection cooling by molecules of surrounding gas. Fine tungsten wire is commonly used in these sensors, that are very similar to incandescent lamps, even if they are operated at temperatures not exceeding 500ºC. By the way, a similar principle was used in some little known attitude sensors, the ‘Convectrons’ made by Bendix, to measure their inclination with respect to vertical plane.

Thermocouple sensors. In the Pirani sensor a single filament acts both as heater and as temperature sensor, while in the thermocouple the two elements are separated. The temperature sensing element in this case is a thermocouple, that is the junction of two different metals. Here by thermoelectric effect we find an emf proportional to the temperature of the joint. This kind of sensor has in the same envelope the heater and the thermocouple assembled side by side. Hence this device has four wires, two for the biasing current port and two for the voltage sensing port.

Cold cathode ionization sensors. The Penning sensor, by the name of its inventor Frans Michel Penning, operates in a magnetic field. Here the ionization takes place because of the quite high voltage applied to electrodes.

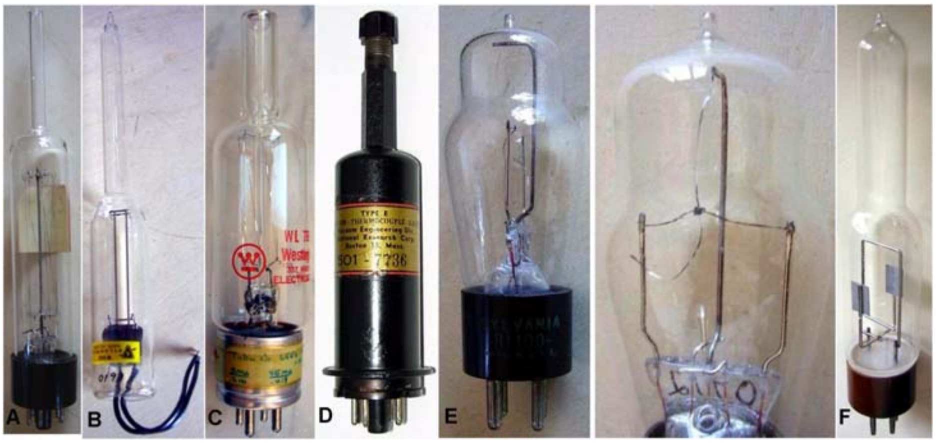

Fig. 8.2.9 - Vacuum sensors. A) Raytheon CK1300 was a Pirani vacuum gauge not documented, but for its resistance value written on the label. B) Sylvania R1111 measures from 15.5 to 17 ohms at 100 mA. C) WL-765 was another Pirani gauge from Westinghouse. D) 501-7736 by NRC was an E-type thermocouple. E) Two views of Sylvania R1100 thermocouple. In the enlarged view the tiny joint of the thermocouple and of the crossing heater can be appreciated. F) Philips CIG-22 was a Penning vacuum sensor, exploiting the ionization of rarified gases under high-voltage fields.

Hot-cathode ionization sensors were very similar to vacuum triodes. Their operating principle is based upon measuring the ion current in the collector, which decreases as vacuum increases. The grid is biased positive with respect to filament, attracting and accelerating electrons emitted by the filament. Anode is biased negative and acts as collector for ions derived from impacts of electrons on gas molecules. In the Bayard-Alpert sensor the geometry of electrodes is modified for better efficiency. Filament is mounted outside the grid helix and anode is a small filamet in the middle.

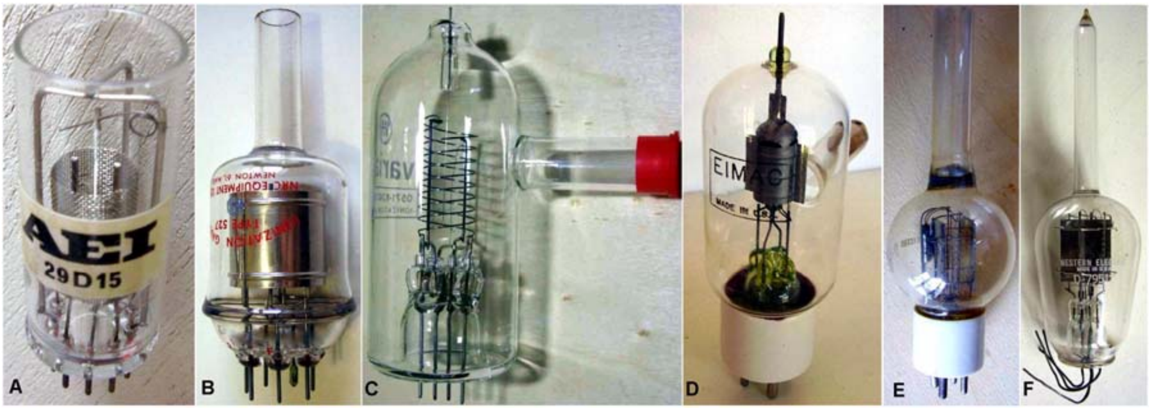

Fig. 8.2.10 - Some samples of hot-cathode ionization vacuum sensors. Recent types were made to a special Bayard-Alpert design, with filamentary anode in the center of a cylindrical grid and the filament outside. In the past ionization sensors were derived by minor changes to standard triodes. A) Thorn-AEI 29D15 shows a modern Bayard-Alpert structure in a 9-pin miniature glass envelope. B) NRC 527 looks to be a classic ionization gauge. C) Varian 571-K2741 is a Bayard-Alpert ionization gauge based upon filamentary electrodes, in order to facilitate degassing. D) This Eimac ionization gauge looks to be directly derived from their 35T transmitting triode, with a glass tubulation added on the side wall. E) Western Electric D-79510 looks to be derived from their 205B / VT-2 triode. Nonex bulb and ceramic base in this sample. F) The same electrode structure is retained in this pear-shaped D-79512. In this case however flying wires are left for connections.

> Back to main index <

> Go to the sensor index <