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Application Note AN-0208-1

Use of the Plateau Function with DP Detectors

Purpose: This document expands and clarifies the use of the plateau function on Protean Instrument Corporation systems equipped with the DP (dual phosphor) detector. This document constitutes Protean Instrument Corporation's factory recommended operation of the plateau function, and outlines the critical portions of any procedures relating to setting the operating voltage, bias point, or plateau for this system.

Background: Protean systems can be equipped with several detector types. The detector most commonly used is a gas flow proportional style. Gas flow proportional detectors have been used for nuclear counting for many years and their general operating characteristics are well known. Most people who use instruments with gas flow proportional detectors are familiar with the requirement to establish the plateau region and select an optimum operating voltage but few understand the influencing parameters and why they are important. An often-made mistake is trying to apply tests designed for gas flow detectors to other styles of detectors. Whatever the detector, selecting and maintaining the operating voltage is critical to the instruments performance because it ultimately determines the counting efficiency of the detector and the discrimination between alpha and beta particles.

When a gas filled detector is operated in the proportional region, the implication is that the amplitude of the pulse produced by total absorption of the alpha or beta particle is proportional to the energy of the particle. The amplitude of the pulse will vary with the bias voltage but only one pulse will be produced. At lower bias voltages, the pulse is not detectable by the electronics. At higher voltages, the gas breaks down or avalanches and multiple pulses are produced. The latter is the Geiger range.

The proportional region is determined by plotting the count rate response as the bias voltage is gradually increased or stepped. The resulting curve increases from no counts to a gradual increase followed by a relative flat response and finally a high slope area. The relatively flat area is referred to as the plateau area. This is the desired operating region for a gas proportional detector because relatively large changes in bias voltages will not grossly affect the count rate. A unique characteristic of the gas flow detector is that the bias voltage (with respect to the detectors anode to cathode) can effectively change in the range of 10 to 20 volts due to space charge affects in the presence of high activity sources. With low level counters, it is also desirable to operate at as low a voltage as possible in order to reduce the background. With this in mind, the need to accurately define the beginning or knee of the plateau should be apparent. If this knee is known, the optimum bias setting is 30 to 50 volts above the knee thus providing adequate room for bias shifts without falling off the plateau while also assuring that the voltage is kept at a minimum for the sake of the background.

Another crucial bit of information is that the knee will vary depending on the energy of the beta particle. Detectors designed for low beta background actually respond in an inverse proportional manner with respect to the energy of the beta particle. In other words, lower energy betas will produce a larger amplitude pulse than a higher energy beta. This assumes that the beta has sufficient energy to penetrate the entrance window. Obviously higher amplitude pulses are easier to detect. If there were such a thing as a monoenergetic beta source, the knee on a low energy monoenergetic beta plateau would occur at a lower bias voltage than the knee on a high-energy monoenergetic beta source. Since naturally occurring beta sources have a broad range of energies, the aim of the bias setting should be to look for the worst-case condition (i.e., the knee of the higher energy betas). For this reason a Sr/Y-90 source is a good choice because of the higher energy contributions of the Y-90 betas. To preserve the high energy response it is important to minimize wide angle scattering effects such as found in distributed sources or sources exhibiting high backscatter. This requires the use of a point source positioned as near to the detector's entrance window as practical during the generation of the detector response curve.

<u>Most of these details pertain only to the gas flow proportional detectors</u>. The gas flow detector exhibits excellent performance but requires a constant supply of counting gas, usually P-10. This is a drawback for some applications and users. The DP detector is used for applications where a supply of P-10 gas is difficult or impossible to provide. The DP detector provides similar counting performance, but operates in a fundamentally different way.

The DP detector consists of 2 critical subassemblies, a photo-multiplier tube (PMT) coupled through a light pipe to two scintillators. The scintillators are zinc sulfide on the outside and a thin proprietary plastic disk nearer to the PMT. The zinc sulfide responds to alpha emissions, and the plastic responds to beta emissions. Both scintillators generate light pulses, which are detected and amplified by the PMT. The plastic beta scintillator is kept thin to insure optimum light transmission to the PMT and to insure amplitude differentiation between light bursts resulting from the two scintillators. The result is that each scintillator generates pulses of characteristic amplitude. The differing light bursts from the scintillators result in distinguishable pulse amplitudes after amplification from the PMT and amplifiers. Particle discrimination is possible due to the response of the scintillators, not the characteristics of the PMT.

If an operating curve is produced for a DP detector in the same fashion as for a gas flow proportional detector, a similar shaped response curve is expected however the flatness (slope) of the "plateau" region is not comparable for the following reasons:

1. Slopes for DP detectors are greater than gas filled detectors because the gain change per voltage step is much greater for a PMT than for a gas proportional detector.
2. The thin beta scintillator does not absorb the entire energy of the beta particle making it more susceptible to losses due to scattering effects than seen with large volume gas filled detectors. As with the gas filled detector, distributed sources will increase the slope due to a wider dispersion of beta energies.
3. It is important to understand that it is not critical to have a well-defined slope in a DP detector because it is not subject to bias variations due to the space charge effects as is the proportional detector. The bias of the PMT is maintained within $\pm$ 2 volts with a highly stable and regulated power supply. The efficiency (gain) loss associated with PMTs is mostly due to long-term aging of the photo cathode, which takes years to show up.

Regardless of the type of detector used in a nuclear counting instrument, it is necessary to control the detector gain and maintain it at a known and stable value. In any system using a PMT based detector, it is necessary to have some means of adjusting the operating voltage to correct for aging effects as pointed out in point 3 above. As a part of the manufacturing procedure, Protean selects the optimum operating voltage for each of its systems that utiliizes a DP detector through standardized testing with point sources. The instrument is tested and shipped with this voltage setting and a beta response curve stored in memory. This factory procedure requires the use of a Sr/Y-90 point source centered and elevated to the top of the sample carrier. With sufficient count time to accumulate a minimum of 10,000 counts per point in the plateau region the plateau slope should be <= 5 % per 100 volts over a 75 volt region. The factory slope criteria provide us with the assurance that the DP detector assembly meets our manufacturing standards for uniformity. Keep in mind that slope measurements with a DP detector and a beta source are very subjective and very dependent upon the characteristics of the specific test source. Stable operation is not dependent upon the slope of the "pseudo plateau". Factory curves are not reproducible unless a similar counting geometry and a point source is used. The value of a customer produced response curve is as a diagnostic tool rather than as a quality control procedure.

Protean's firmware and hardware includes provisions for setting and maintaining the operating voltage for the detector. These provisions are part of the plateau function in the system. The plateau function also contains a means to step the operating voltage in defined increments, count a reference source at each step, and plot the results. When the instrument is first received, it is recommended that a hard copy of the factory generated "plateau" curve be printed and saved and the voltage settings recorded and saved. It is also recommended that a stable beta source be used to generate an on-site curve for reference only. DO NOT CHANGE THE VOLTAGE SETTINGS.

Efficiency calibrations and backgrounds should be determined and an efficiency check regime established. Should a change in efficiency outside acceptable statistical limits indicate a possible problem, a detector response curve may be generated and, if so indicated by a shifting of the curve towards a higher voltage, the voltage may be increased to compensate for PMT aging. If the detector is replaced, then the correct operating voltage for that detector will be supplied, and should be set using the plateau set functions.