INDUSTRIAL ANALYSIS POSSIBILITIES USING LONG-LIFE SEALED-TUBE NEUTRON GENERATORS

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Long-life sealed tube neutron generators appear very attractive for use in industrial systems, because of their modulation and their high neutron output capabilities. SODERN is now able to put on the market different types of transportable neutron generators, designed for intensive use, called GENIE. The main potential applications are: high sensitivity measurement of transuranic elements in nuclear waste drums, in situ measurements for oil and mineral logging, process control for bulk material or in metallurgy, hidden explosives detection, neutron radiography, etc…. The present paper shows some examples of how to use such generators most effectively.

INTRODUCTION

Long-life sealed tube neutron generators are characterized by interesting properties. The first is related to the deuterium-tritium or deuterium-deuterium fusion spectrum: the very sharp neutron energy spectrum makes any selective nucleus excitation possible, either at 14 MeV or at 2.5 MeV. The second is a neutron output level adjustable to such high level as $10^{11}$ n/s or more, in continuous or pulsed mode, associated with the on/off character of such generators. The neutron output in a wide range ($10^7 - 10^{11}$ n/s or more) may be delivered without any excessive radiological arrangements due to tritium hazard or to a residual activation of the installation. A third interesting feature for analysis is the pulsed mode at frequencies up to 10 kHz, which is not possible with radioisotopic sources or nuclear reactors.

Using the pulsed mode, more selective excitations of material under examination are possible and, by means of synchronized detection techniques, prompt gamma-ray spectra due to either inelastic or capture interactions can be distinguished leading to better signal to background ratios and more powerful analysis. Another possibility is the activation of very short lived excited states of elements (between 100 μs and 100 ms, or more). In order to take advantage of these properties for industrial applications long life neutron generators were designed and realized in transportable versions by SODERN, under the name GENIE. Tests show a working time of a few thousand hours, according to the tube type and the selected neutron output.
There are two main fields of industrial applications of GENIE equipments:
- industrial analysis mostly for on line process control, ground logging, security check
- non destructive testing by neutron radiography and by spectrometric analysis.

SEALED-TUBE NEUTRON GENERATORS

Sealed tube neutron generators use the following nuclear reactions:

\[
\begin{align*}
D + T & \rightarrow ^4\text{He} (3.6 \text{ MeV}) + n \ (14.1 \text{ MeV}) \quad (1) \\
D + D & \rightarrow ^3\text{He} (0.8 \text{ MeV}) + n \ (2.45 \text{ MeV}) \quad (2) \\
D + D & \rightarrow T (1 \text{ MeV}) + H (3 \text{ MeV}) \quad (3)
\end{align*}
\]

The first two fusion reactions (1) and (2) are very neutron prolific even at low ion energies. The third one, (3), of equal probability as (2), does not deliver neutrons. On this basis, two kinds of industrial generators were designed by SODERN.\(^{12}\)

The first kind is based on reaction (1) which is the more effective. In this configuration, a mixture of deuterium and tritium ions is accelerated at more than 100 kV into a tritiated target. Monoenergetic neutrons at 14 MeV are emitted in a near isotropic manner. Neutron emission is controlled either in continuous mode, or in pulsed mode at frequencies up to 10 kHz. These generators are very interesting, for their high output and their high neutron energy. The working time of the sealed tubes is long. Thus, the TN 26 B SODERN tube has a lifetime of the order of a few thousand hours for a continuous emission at \(10^8\) n/s, and the TN 46 a lifetime of more than fifteen hundred hours.

<table>
<thead>
<tr>
<th>Generator type</th>
<th>Tube type</th>
<th>High voltage power supply</th>
<th>Neutron output (n/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENIE 46</td>
<td>TN 46</td>
<td>225 kV</td>
<td>(10^{10}) to (10^{11})</td>
</tr>
<tr>
<td>GENIE 26</td>
<td>TN 26B</td>
<td>125 kV</td>
<td>(10^7) to (10^8)</td>
</tr>
</tbody>
</table>

Table 1

Neutron emission of some SODERN generators