Applications for Gas-Plasma Target Neutron Generators

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Topics

- History
- Technology
- Innovative Applications Examples
History – since 1996

- 1996-2001
- Q3 2001
- Q4 2001-2004
- 2005
- 2006-2008
- NOW

NSD-Fusion
Innovation

The neutron generator is like a new light source.

To sell it, there have to be applications where it:

Either enables further innovation.

Or replaces obsolete neutron source technologies.

Replace $^{252}\text{Cf}$ (“Unaffordium”)

Overcome short endurance of solid target NGs.
Life Cycle Cost Comparison

- Longest life at full power (years)
- No solid target
- No thermal fatigue
- Long service interval
- Higher output
- Lower price

This is an old chart.

Price of $^{252}$Cf is increasing to 6 times! (off the chart)
Sealed Tube Reaction Chamber

O.D. 135 mm
Length depends on configuration of electrode
Inertial Electrostatic Confinement IEC Fusion

Inventor: Philo Farnsworth (Television)

\[ \begin{align*}
  a) & \quad \text{D}^2 + \text{D}^2 \rightarrow \text{He}^3 (0.82 \text{ MeV}) + \text{n} (2.45 \text{ MeV}) \\
  b) & \quad \text{D}^2 + \text{T}^3 \rightarrow \text{T}^3 (1.01 \text{ MeV}) + \text{p} (3.02 \text{ MeV}) \\
  c) & \quad \text{D}^2 + \text{T}^3 \rightarrow \text{He}^4 (3.5 \text{ MeV}) + \text{n} (14.1 \text{ MeV}) \\
  d) & \quad \text{D}^2 + \text{He}^3 \rightarrow \text{He}^4 (3.6 \text{ MeV}) + \text{p} (14.7 \text{ MeV}) \\
  e) & \quad \text{He}^3 + \text{He}^3 \rightarrow \text{He}^4 + 2 \text{p} + 12.86 \text{ MeV}
\end{align*} \]
Solid target NGs

N/sec ⋅ fusion particle flux onto target

IEC plasma-gas target NGs
beam-beam and beam-background collisions
electrostatic confinement increases fusion probability
destabilizing effects in high pressure (poor vacuum)
limits scaling

NSD-NG highest specific DC performance

Pulsing experiments in USA (UI & UW), Japan (Kyoto)
Super linear scaling with current
Linear n/s \( I^{1.0} \)
Super-linear \( I^{1.x} \) \( x > 0 \) \( I^{1.5} \) => ~10X gain
- Pulsed power allows much higher performance
- Compact pulsed High Voltage Power Supply
- 3% duty cycle
- Maximum input power ~15 kW (3 phase power)
- NSD-Fusion measurement in preparation
Automated Control

NSD-Fusion

Automated Control

Automated Control
Markets for Neutron Generators

**Neutron Generator output**
- **neutrons / sec**
  - $10^8$
  - $10^9$
  - $10^{10}$

**Sub-critical fission power**
- BNCT cancer treatment
- P.E.T. Isotope production
- Medical n-gamma imaging
- Neutron radiography
- Land Mine detection
- On-line letter and parcel inspection
- ContainerProbe
- Industrial on-line and off-line solids and fluids PGNAA
- Car, Parcel and Letter Bomb IED detection
- Baggage inspection explosives detection PGNAA
- Online mineral quality monitoring PGNAA
- Exploration bore hole / mobile PGNAA assay
- Mobile Safeguards inspection (nuclear and chemical weapons)
- Material sorting NiCd/NiMH battery PGNAA
- Radiochemistry laboratories (analytical labs)
- Online Moisture in coal and coke measurement
- Industrial Gauges
Proposed example  (N. Menduev  NSD-Fusion):

**Gamma Release End Time**

What is the Gamma release end time of irradiated sample by PGNAA?

What is the PGNAA parameters of activation?

We need to know the “gamma release end time of many elements activated by PGNAA.

Create Function GET(f,T,t,d,m)= gamma end time after termination of PGNAA.
f(neutron flux),
E(neutron energy ),
t(irradiation time ),
d(distance) and
m(sample mass) dependent function database.
Beginning of $^{252}$Cf life

2.65 years later
EC Research Fund for Coal and Steel wanted a resubmission of proposal for neutron interrogation Prompt Gamma Neutron Activation Analysis PGNAA of scrap in scrap charge buckets for increased recovery of scrap. “Strategic importance”.

Scrap-Probe project started – end 2011
Arcelor Mittal (ES), University Liverpool (GB)
Centre de Rescherches Metallurgique (BE)
Cetto project coordinator (DE)
NSD-Fusion (system integrator) (DE)
Alloy elements %
Carbon % content option.
Water % content option.

Scrap Bucket Probe

ContainerProbe variants in portals ->
TruckProbe for non-ferrous recyclers
RailWagonProbe
Small BucketProbe replaces hand assay
Benefits to Society

- Energy Saving
- Environmental Protection
- Recycling of Materials
- Civil Security
- Safety
- Industrial Quality Assurance incl. nuclear power
- Scientific Research
Tunnel Baggage Neutron Interrogation

Continuous Motion of Conveyor

NSD-NG makes it economic

Rapiscan: large (expensive) neutron generator (accelerator)

Livermore Labs R&D project shows that a moderate output neutron generator can support 30 second scan detection of fissile material.

NSD-NG long segmented line neutron source can deliver more neutrons to probe the container without scanning.

Scanning past a source and detector gives position information and takes time.
ContainerProbe Portal
Promoted to DHS (USA) for 100% Risk Screening of containers (USA Safe Ports Act 2006)

Not financially eligible for EU FP7 Security Research

Since April 2009 U.S.A. - Germany security technology research funding
Fast Neutron Radiography

Deconvolution of neutron source structure.
Further discussion at Poster Paper

or please visit our exhibit booth