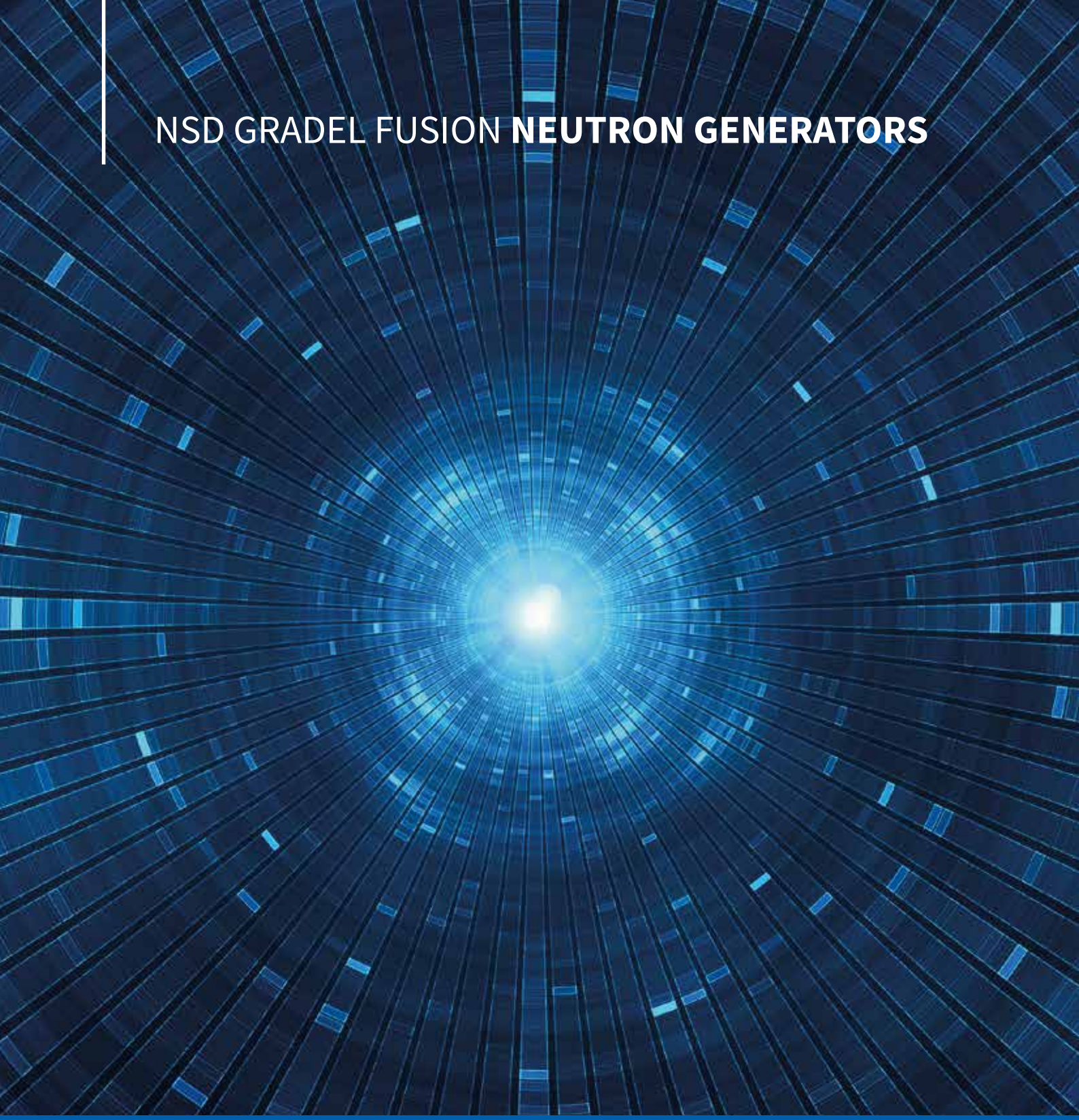
NSD GRADEL FUSION **NEUTRON GENERATORS**



GRADEL

Contents

General

Neutron generators provide materials analysis, non-destructive testing tools and bring cost-reducing capabilities to various industries, including on-line elemental analysis in mining and ore processing, heavy industries, art conservancy, security, and medicine. Electric neutron generators can be switched off but radioactive isotope neutron sources cannot be stopped. Conventional neutron generators impose a high life cycle cost, our generators don‘t. A better type of neutron generator with much longer operating life and a practical geometry are the uniques advantages.

Our patented, long-living neutron generators produce neutrons by fusing isotopes of hydrogen. They do on small scales what the sun does on large scales.

Neutron generator set-up and working principle

Two electrodes are concentrically aligned. The space in between is filled with propellant and reactant gas at low pressure. Adding high voltage makes ignition, ignition leads to fusion, fusion makes neutrons, neutrons lead to revenues. At higher voltage the collision can cause nuclear fusion and the emission of neutrons.

Application possibilities

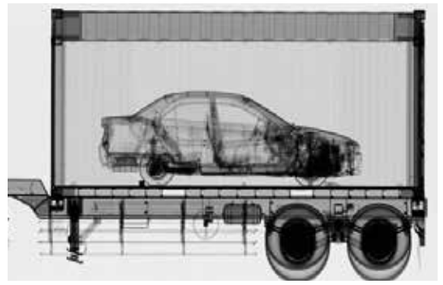
- Pure Neutron Source for applied research
- Radiography / Tomography for quality control and measurement of changes
- Spectroscopy of the gamma photons emitted by matter which is irradiated by neutrons

Application examples in technical terms

Pure Neutron Source for applied research

- Neutron production for testing neutron induced single-event-effects phenomena in electronic systems
- Generation of medical isotopes
- The Boron Neutron Capture reaction is being developed as a medical cancer therapy.

Radiography / Tomography for quality control and measurement of changes

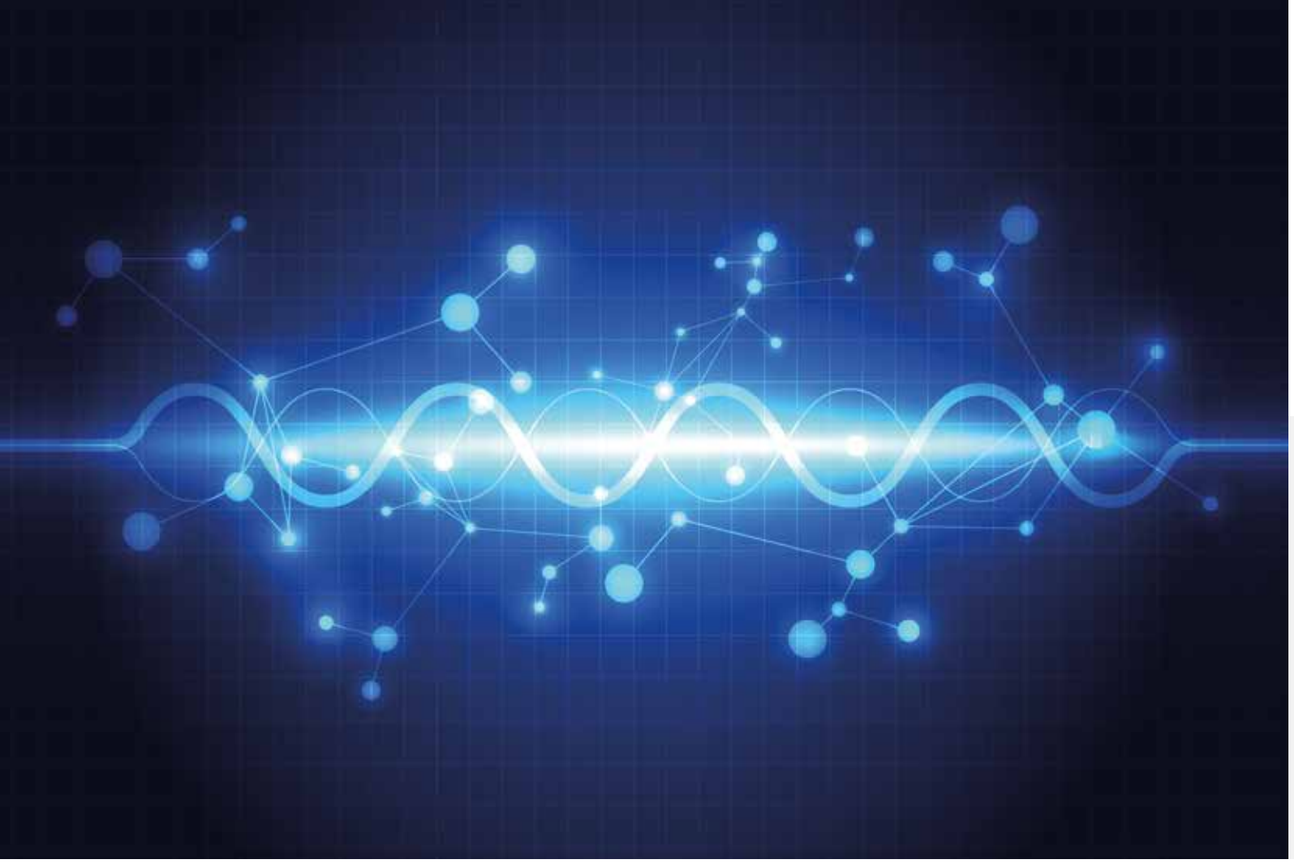


- Larger volumes can be resolved much better than by conventional X-ray. This opens new markets for neutron based radiography applications.

Spectroscopy of the gamma photons emitted by matter which is irradiated by neutrons

- Contraband Detection Systems use the neutron-gamma reactions to measure the spectra and compare the actual with a library of spectral signatures for a possible match of various prohibited substances and exclusion of safe substances
- Security scanning of containers and transport boxes | Homeland Security
- Periodic inspection: Blast furnace liner (carbon, ceramics, copper)
- Measurement of the liquid metal level in the furnace
- Mining industry, online measurement of composition of the extracted mining ore: Coal, iron ore, copper
- Prompt Gamma Neutron Activation Analysis (PGNAA) in production processes ranging from steel (sinter) to cement production mixture control
- Carbon Energy flow into Blast Furnace combined with moisture analysis

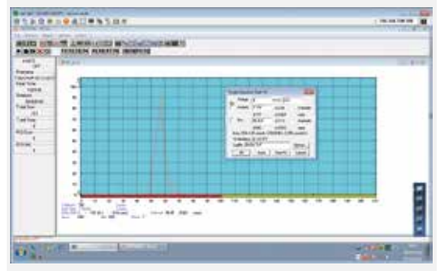
- Explosive Detection Systems that use 14 MeV neutron interactions to measure the relative abundance of unique gamma spectral peaks such as that produced by nitrogen, oxygen and carbon which occurs in almost all explosive compounds
- Composition of shredded scrap (Cu extraction – remaining fraction) Online analysis on a conveyor belt



Our generators

NSD-70-P DD / DT Pulsed Neutron Generator

- Emergency stop and door switch external interlock loops
- Remote connection watchdog
- UN2911 Class 7 accepted transport package
- Dosimeter integration option
- No SF_6
- Gas is stored in a solid getter pump for vacuum pressure at room temperature



Specifications

- Neutron yield ~**2.6E6** DT **n/pulse** 4πsr max*
- DT 14 MeV option ~ 60 x DD output.
- DD 2.5 MeV neutrons or TT neutrons
- Greater than 20,000 hour lifetime (estimated)
- Pulsed operation only
- Pulse rate: single shot, 2 Hz to 2 kHz
- Maximum n/s output at 1 kHz (~2.6e9 DT n/s) with 4 Pulsed Power Units*
- min. 1, max. 8 PPUs for more current per pulse
- Pulse duration: min. 0.7 µsec FWHM, max. ~18µsec
- Rise and fall time: ~ 1 µsec
- Regulated pulsed HV for very stable pulse to pulse repeatability
- High stability, repeatability
- Very low jitter
- Synchronizing “TTL” signal
- Outer casing is at ground potential
- Closed loop water cooling
- Neutron emission module ~12 kg
- Input power 400Vac ±10% 3-phase with neutral 50-60 Hz ~3kW
- VNC remote control over LAN

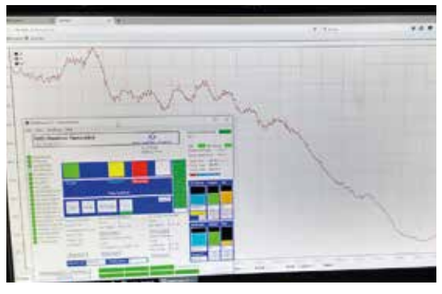
Advantages of our neutron generators and infrastructure

- Electrical source; no neutrons when switched off
- Best life cycle cost ratio compared to solid target neutron generators or Cf 252 isotopes due to high reliability and low maintenance requirement
- Designed for industrial applications, can operate under water
- Different sizes (neutron flow) and lengths available
- Neutron pulses which are precise, short (1µsec) sharp and no jitter
- Licenced neutron test facility at premises for convenient development phase
- Supply of customized bespoke complete measurement systems from one hand
- 5 versions in operation for different applications (PGNAA and neutron radiography)
- Modular emission unit for adaptation to new applications

NSD-350-8 or 18-C Neutron Generator

DD 2.5 MeV or DT 14 MeV options

- Intelligent fail-safe automation control
- Emergency stop and door switch external interlock loops plus extra inputs for dosimeter alarm signals
- Remote connection watchdog
- LB112 dosimeter integration interface
- UN2911 Class 7 excepted transport package (applicable to DT or TT only)
- No environmentally harmful SF_6 -gas
- DD/DT/TT gas is stored in a solid getter pump for vacuum pressure in the sealed reaction chamber at room temperature (no risk of outward gas leakage)
- No breakable glass components



Specifications

- Electrode and fusion emission zone length in middle of reaction chamber: **350 mm**
- DD 2.5 MeV neutron yield: maximum ~4 x10^7 n/s output with 8 kW and ~9 x 10^7 n/s with 18 kW
- DT 14 MeV neutron yield (65 x DD)
- max. input power 8 or 18 kW high voltage DC
- Greater than 20,000 hour lifetime
- Non-pulsed continuous operation
- Quick start to near full output
- Stable and repeatable operation
- Outer casing is at ground potential
- Reaction chamber: 1300 mm long. 135 mm O.D.
- Neutron emission module ~ 25 kg
- Input power 400VAC ±10% 3 phase Y configuration
- VNC control HMI over LAN via any PC
- OPC or Webservice for integration into systems
- Automated unattended operation for industrial applications
- Submersible option
- Neutron count rate (accepts neutron detector pulses) and availability monitor for gating of momentary outages.

NSD-350-24-C Neutron Generator

DD 2.5 MeV or DT 14 MeV or TT 0.5 - 9.5 MeV options

- Intelligent fail-safe automation control
- Emergency stop and door switch external interlock loops plus extra inputs for dosimeter alarm signals
- Remote connection watchdog
- LB112 dosimeter integration interface
- UN2911 Class 7 excepted transport package (applicable to DT or TT only)
- No environmentally harmful SF_6 -gas
- DD/DT/TT gas is stored in a solid getter pump for vacuum pressure in the sealed reaction chamber at room temperature (no risk of outward gas leakage)
- No breakable glass components

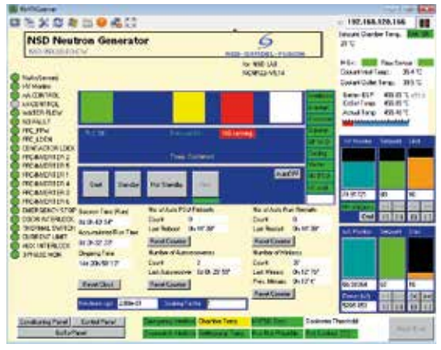
Specifications

- Electrode and fusion emission zone length in middle of reaction chamber: **350 mm**
- DD 2.5 MeV neutron yield: >1 x10^8 n/s output
- DT 14 MeV neutron yield (65x DD): >5 x 10^9 n/s
- TT 0.5-9.5 MeV neutron yield: ~3x DD (TBC)
- max. voltage 140 kV max. current 150 mA
- Greater than 10,000 hour lifetime
- Non-pulsed continuous operation
- Quick start to near full output
- Stable and repeatable operation
- Outer casing is at ground potential
- Reaction chamber: 1300 mm long. 155 mm O.D.
- Neutron emission module ~ 30 kg
- Input power 380/220VAC ± 10% or 415/240VAC ±10% by 3 phase configuration to HV PSU
- VNC control HMI over LAN via any PC
- OPC or webservice for integration into systems
- Automated unattended operation for industrial applications
- Submersible option
- Neutron count rate (accepts neutron detector pulses) and availability monitor for gating of momentary outages.

NSD-50 Neutron Generator

DD 2.5 MeV or DT 14 MeV or TT

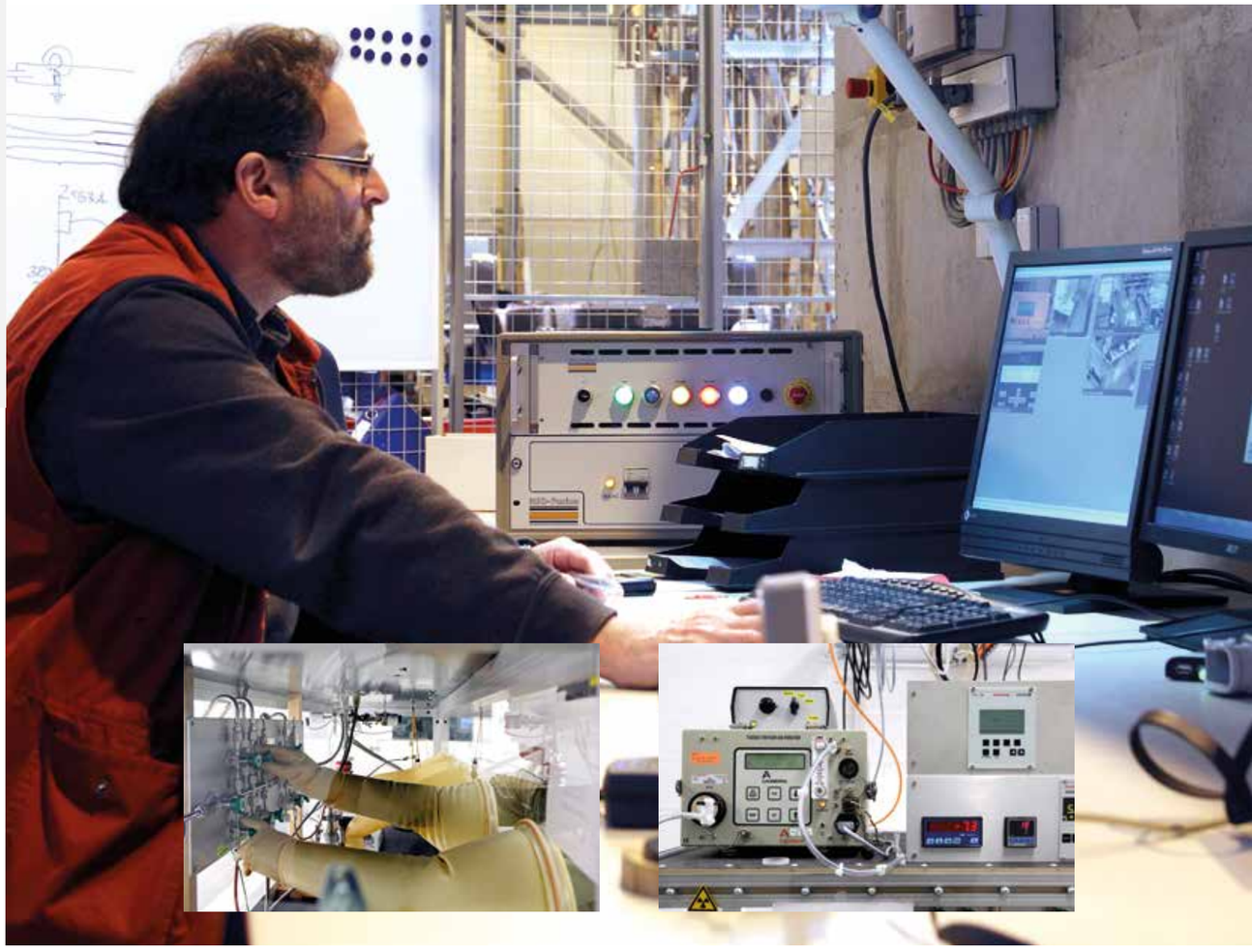
- Intelligent fail-safe automation control
- Emergency stop and door switch external interlock loops plus extra inputs for dosimeter alarm signals
- Remote connection watchdog
- LB112 dosimeter integration interface
- UN2911 Class 7 excepted transport package (applicable to DT or TT only)
- No environmentally harmful SF_6 -gas
- DD/DT/TT gas is stored in a solid getter pump for vacuum pressure in the sealed reaction chamber at room temperature (no risk of outward gas leakage)
- No breakable glass components



Specifications

- Electrode and fusion emission zone length in middle of reaction chamber: **50 mm**
- DD 2.5 MeV neutron max. yield: ~4 x10^7 n/s
- DT 14 MeV neutron max. yield: > 3 x 10^8 n/s
- max. voltage: 120 kV
- max. current: 15 mA
- Greater than 20,000 hour lifetime
- Non-pulsed continuous operation
- Quick start to near full output
- stable operations and starting from lowest (~1000 n/s DD) to highest output
- High stability and repeatability
- Outer casing is at ground potential
- Reaction chamber: 815 mm long, 135 mm O.D.
- Neutron emission module weight: ~12 kg
- Input power 230 or 110/220 VAC 50/60 Hz, 3 kW
- VNC control HMI over LAN via any PC
- Automated unattended operation for industrial applications
- Neutron monitoring for connection to a neutron detector and TTL signal for neutron emission
- Complete plug and play system includes everything required except a PC for VNC access: NG head, central control unit, power supply, cooling unit, cables

References



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KGG Kernkraftwerk Gundremmingen GmbH · IEAv · SYSKON

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