ORTEC®

Fission Meter

Portable Neutron Source Identification System

"Another hugely significant new tool from ORTEC for the interdiction of fissionable material."

AMETEK®
ADVANCED MEASUREMENT TECHNOLOGY

Fission Meter

- **"Proof Positive" identification of fission neutron sources, through multiplicity analysis.**
- **Ultra-low level false positive and negative rates, even in the presence of high neutron background.**
- **Immune to cosmic background fluctuations.**
- **Highest sensitivity in a portable package.**
- **Easy to operate.**

The detection of illicit radioactive material is highly important in homeland security applications worldwide. There is great concern about Radioactive Dispersal Devices (RDDs), but the destructive power of these terrorist weapons is small compared to that of a nuclear explosion produced by an Improvised Nuclear Device (IND) or state-built nuclear weapon. Even a crude nuclear device could have an explosive power equivalent to 250 Kilotons of TNT. A nuclear explosion requires the presence of so-called Special Nuclear Material (SNM), that is, Uranium or Plutonium. The major technical challenge is to detect and identify SNM rapidly and with certainty. The most common approach to the detection of RDD or IND devices is through their gamma-ray signatures. However, heavy metal shielding may ultimately defeat such methods.

The Fission Meter aids the interdiction of illicit trafficking by augmentation of gamma-ray identification with a neutron detector of very high sensitivity which, in addition, can specifically identify fission neutron sources by the inherent characteristics of the decay process. Gamma-rays are 100 times more abundant than neutrons so the gamma-ray nuclide identifier such as the ORTEC Detective* will always be first choice, providing the easiest way of source location. Identification, not simply detection, of gamma-rays and neutrons is required; both exist in normal background and their signatures may be similar to those of illicit nuclear material. Circumstances arise where reliance on a gamma-ray detector alone comes into question; the package may be large enough to contain significant shielding, or the gamma-ray background may be seen to drop when measuring a particular package-indicating heavy shielding. The hand-held identifier's neutron detector may show an elevated neutron count rate, or the gamma-ray spectrum may "see" evidence of gamma-rays from neutron reactions. **Many neutron detectors exist but all other neutron detectors which might be used in the field, are limited to basic counting.** They can register the presence of neutrons, but nothing else. What is needed is a way to check a package or the environment for the existence of neutron sources beyond what would be expected from background.

The most challenging interdiction situation, for which the Fission Meter is designed, is the case where the neutron count rate is between average background and about ten times average background, although the instrument is capable of handling total count rates of 500,000 counts per second. These higher neutron fluxes are readily detectable with the Detective. When these neutron-radioactive packages are considered, the shipping documentation either justifies the circumstances or the package will be selected for further study. This slightly-elevated count-rate regime is challenging because legitimate, non-fissile cargo can cause up to a ten times increase in background due for example to the interaction of Cosmic rays with nearby metal such as cast iron, a process known as "Spallation."

Fission Meter Operational Modes

Three Fission Meter operational modes are useful in these circumstances: Mobile Search, Static Search (identification), and Characterization or "reach back."

Mobile Search is the process where a detector is used to localize a neutron source. If a package is found, or is targeted, the Static Search mode is next used for deciding if there are shielded "non-cosmic" real neutron sources present. (As opposed to a high neutron background due to cosmic ray interactions.)

Identification refers to the process of making a distinction between true background neutrons and non-background neutrons. Characterization data collect "reach back" is the process of sending the neutron data collected to a "home team" or specialist for more detailed multiplicity analysis. The reach back process assesses more closely the hazard associated with the found neutron source. If a source is multiplying significantly, the operator will see a signature and can respond appropriately.

*http://www.ortec-online.com/solutions/hand-held-radioisotope-identifiers.aspx

Fission Meter

The Fission Meter Principle

The Fission Meter is a sophisticated neutron detector. It can identify fissionable Uranium (U) and Plutonium (Pu), by evaluating the distribution in time of neutrons that are emitted spontaneously by these materials. The Fission Meter Technology is the most advanced technology available to segregate threat from non-threat neutron sources. The technology has been developed at Lawrence Livermore Laboratory* and is licensed to AMETEK's Advanced Measurement Technology ORTEC Division. It is entirely complementary to the LLNL gamma-ray technology embodied in the Detective family of nuclide identifiers and in the ORTEC Detective-SPM Spectroscopic Portal Monitor.

A characteristic of SNM sources is that the radioactive decay of each nucleus produces MULTIPLE neutrons, which are released as the nucleus flies apart after the so-called spontaneous fission. Detection of these neutrons, which largely pass thought heavy metal shielding, provides a second or confirmatory method to detect SNM. Cosmic-ray induced neutrons are produced by about seven different creation mechanisms that release neutrons distinctly different from fission. Everyday, a typical inspection area is bathed in a flood of cosmic-induced neutrons that vary in intensity from container-to-container or area-to-area by up to a factor of ten. **This forces one to set the threshold for a moving neutron search detector to about a factor of ten higher than a local background average.**

The feasibility of a nuclear explosion relies on the so-called chain nuclear fission reaction. SNM is "special" because of its copious production of neutrons, which make fabrication of a weapon possible. The number of neutrons associated with a single nuclear fission is a statistical quantity, referred to as "multiplicity," but the key factor is that it is in the range 0–7 and usually greater than unity; the neutrons released are produced by a single decay and occur in a short time window. The neutrons are said to be correlated. Correlated neutrons are an indication of both spontaneous fission and neutron multiplication, both of which are present in a weapon. However other neutron sources, such as Cf-252, emit multiple neutrons from spontaneous fission but cannot practically be used in an explosive device. To be practical for a weapon, material must emit multiple neutrons, but also these neutrons must be able to induce further fission reactions in order to produce the famous chain reaction which creates the explosion.

Neutron sources are more common than is often realized. They are used in a variety of industrial applications; nondestructive testing and oil well logging being two good examples. Detection of an unexpected neutron source, therefore, is not necessarily an encounter with a potential nuclear weapon, and just as it is imperative in gamma-ray systems not to be "fooled" into believing kitty litter to be a weapon or RDD, (or vice versa), false negatives and positives in neutron detection represent the same problem: false positives impede commerce and traffic flows, false negatives have much worse consequences. Neither is desirable.

The Influence of Cosmic and Other Sources of Neutron Background on Performance

"Gross-counting" neutron detectors suffer from the limitation that neutrons detected by them in the environment are indistinguishable from those emitted by a source. The gross counting system has no means of distinguishing an "SNM Neutron" (correlated) from a non-SNM neutron (non-correlated). Moreover, periodic cosmic ray showers produce neutron bursts which represent a substantial increase in background and cause false alarms in a gross neutron counter. These showers are also correlated, but do not cause false alarms in the Fission Meter System, because it is able to analyze the multiplicity distribution of emitted neutrons. Moreover, if there is SNM present, the cosmic ray bursts cause fission in the material **thereby increasing the sensitivity** of the system rather than the reverse as occurs in a gross counter. In fact, it is in principle possible to assay significant quantities of uranium passively by this means.

*LLNL License TL-01962.

Fission Meter

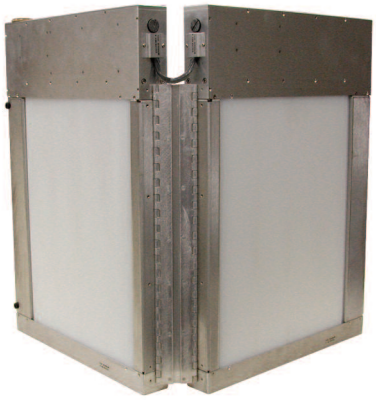
Fission Meter System Overview

The basic components of a Fission Meter System are:

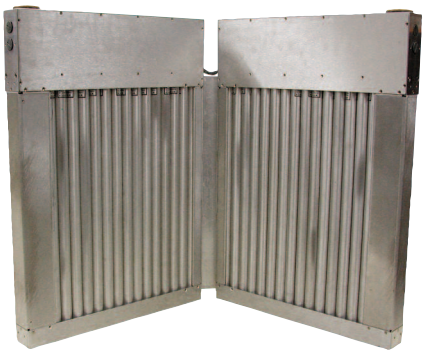
Detector
The detector sub-system consists of multiple moderated 7.5 atmosphere ^{3}He neutron detectors. The detector sub-system includes the HV supplies for the He tubes and the preamplifier/discriminator units required to achieve the pick-off of the neutron events.

Electronics
The electronic sub-system processes the count data from the detection system. By measurement of the relative time intervals between neutrons arriving at a detection system, the statistical distribution of the "multiplicity" may be built up by the electronic sub-system. The electronic coincidence system takes each neutron detected and looks in up to 512 time interval gates to record the time interval between each neutron and others in the data stream from the detector.

Fission Meter Software
The software application analyzes the output from the electronic sub-system to determine if it is consistent with an innocent neutron source or with uranium or plutonium.



Fission Meter hardware removed from carry bag, showing moderator side.



Fission Meter hardware showing ^{3}He tubes.

The Portable Fission Meter System: FM-P3

The portable Fission Meter System is easily carried in a vehicle and can be deployed rapidly against a suspect package or object. At 57 lbs., it is easily carried by a single individual. It comprises two panels of Moderated He detectors, hinged in the center, with integrated electronics powered by readily available D-Cell alkaline batteries. The Fission Meter software operates on an associated ruggedized hand-held computer included with the system.

FM-P3 Detector System

The FM-P3 Detector System represents the highest neutron sensitivity of any commercially available portable neutron detection system of its type. The system includes thirty 1-inch diameter x 19-inch active length He tubes, 15 in each hinged panel. Each panel has an individual HDPE moderator. Adjacent pairs of detectors share a common preamplifier.

Fission Meter

FM-P3 Electronics

The portable "5-mode neutron counter," which is common to other Fission Meter models, is integrated into the FM-P3 Detector System. It has the functionality needed to support the 30 detectors in the FM-P3 Detector System and the control necessary to operate as a standalone fission meter, although conventionally it is operated in conjunction with the Fission Meter Software.

LCD Displays: Neutron counts per second, battery capacity, cycle count.

Push Buttons: On/Off, Start/Stop/Clear.

Counting Modes

Search Mode: The FM-P3 Detector System counts single neutrons with reference to a background threshold to enable the location of neutron sources. The background is usually set in a location known to be free of neutron sources before use. It can be updated automatically or manually.

Analyze Mode/Multiplicity Counting: The FM-P3 Detector System gathers the neutron data and analyses for coincidences; singles, doublets, triplets, and quads up to a very high order. Neutron multiplicities in various time sub gates during each Data Acquisition Cycle are recorded. The acquisition cycle is defined as 512 time bins. This is subsequently analyzed by the system software, according to the Feynman Variance Technique.

Computer Control

All settings and control of the instrument may be accomplished through a standard serial port. An internal switch may be used to set the baud rate to 9600, 14.4k, 19.2k, 38.4k, 57.6k, or 115.2k. The format is 1 start bit, 8 data bits, no parity, and two stop bits. The connector is a 9-pin Female connector that is wired such that a straight cable (not a null Modem Cable) may be used to connect the instrument to a computer.

Fission Meter Controller*

The Fission Meter is supplied ready for use with a controller computer. The controller computer is a rugged TDS Ranger 500X. More details are available from the TDS website (www.tdsway.com). Brief specifications include:

- Processor/Speed: Intel XScale 520 MHz.
- Memory SDRAM: ~22 MB, reserved 128 MB.
- Data Storage (On-board Flash): ~40 MB, reserved 512 MB.
- Wireless (optional): Integrated 802.11g
- Microsoft Windows Mobile™ 5.0
- 53 Tactile Keys with separate navigation, alpha and numeric keypads, and 8+1 directional pad.
- Touchscreen
- Battery Life: 30 hours under normal operating conditions. Complete recharge in 4.5 hours (80% in 2 hours).
- Battery Charge Status LED indicator.
- Notification LED.
- Rugged polycarbonate shell.
- Integrated speaker and microphone.

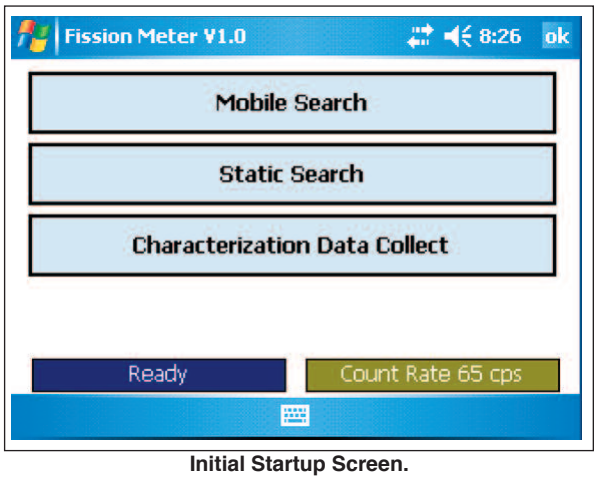
TDS Ranger 500X.

*Specifications subject to change without notice.

Fission Meter

Software

The Fission Meter FM-P3 model is supplied with software that operates on a portable computer included with the system. This software is designed for ease of use in the interdiction application. Minimal operator entry is required. The figure on the right shows the initial startup screen.

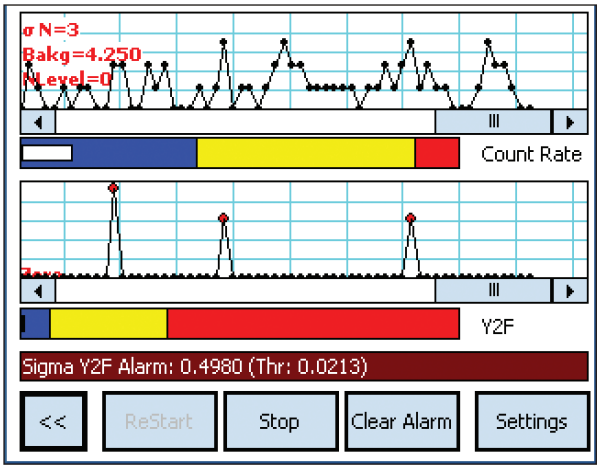


Initial Startup Screen.

Mobile Search

Mobile search is carried out in "real time" to locate a source. In this mode, the user may monitor total (singles) count rate above background (in std deviations) in order to locate a source. (Upper trace and "barometer.") The upper trace gives the historic values as a "strip chart," while the barometer gives instantaneous values against an alarm threshold.

The quantity "Y2F" in the lower trace and barometer is the Feynman Variance. Which is zero for a cosmic source and non-zero for a correlated source.*



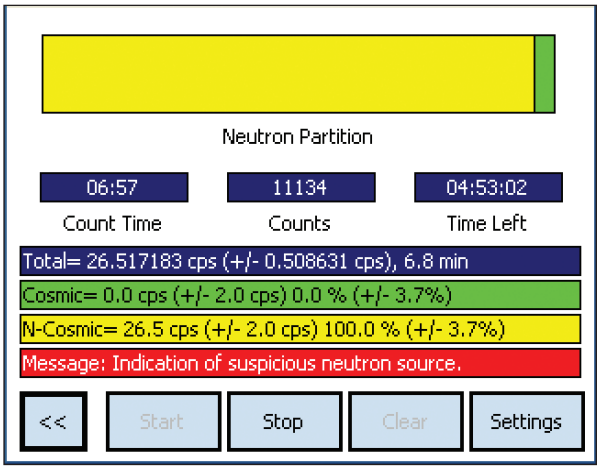
Mobile Search Mode.

Static Search

Once the source has been located, the system is put into position and the data is collected for a longer period, say 15 to 20 minutes in Static Search mode depending on the source strength. (If a package is already suspect, clearly the mobile search step may be skipped.)

At least 30,000 counts must be obtained from the source, which typically implies a count time of at least 1000 seconds for Static Search mode. The Algorithm REQUIRES a static measurement to make the Static Search determination.

By analysis of the multiplicity spectrum, using the Feynman Variance Technique, Static Search mode provides the user with a clear indication of presence of NON-COSMIC neutrons, that is neutrons due to a fissioning source. If the count rate is adequate, and the source is significantly multiplying, Static Search will indicate that this is the case.



Static Search Mode.

*For a reference to the Feynman Variance technique, see for example: LA-UR-90-732 Reilly, D., Ensslin, N., Smith, H., Kreiner, S. (ed) "Passive Nondestructive Assay of Nuclear Materials" ISBN 0-16-032724-5.

Fission Meter

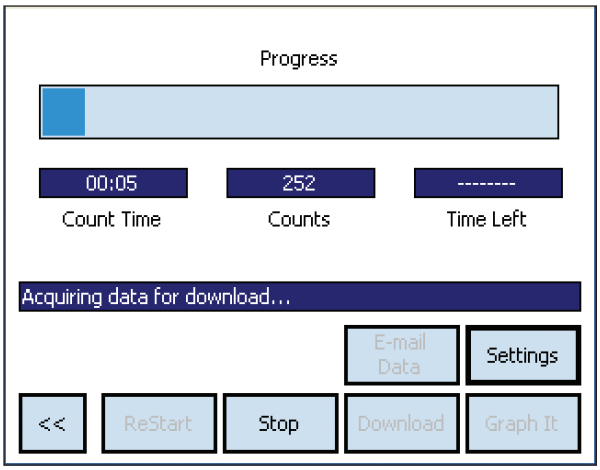
Characterization Data Collect

Following the determination by Static Search mode that an actual fissioning neutron source is present, this mode allows for the collection of much more data (~1 million counts) for expert analysis elsewhere.*

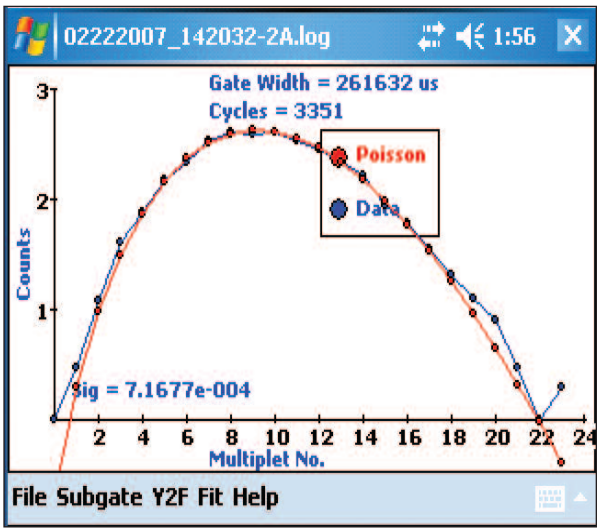
Graphical Plots ("Graph It")

Two plots can be produced. The first is the multiplicity plot. It shows a poisson distribution, matched in mean count to the data. It is the deviation of the data which may include non-cosmics from a purely random (poisson) distribution.

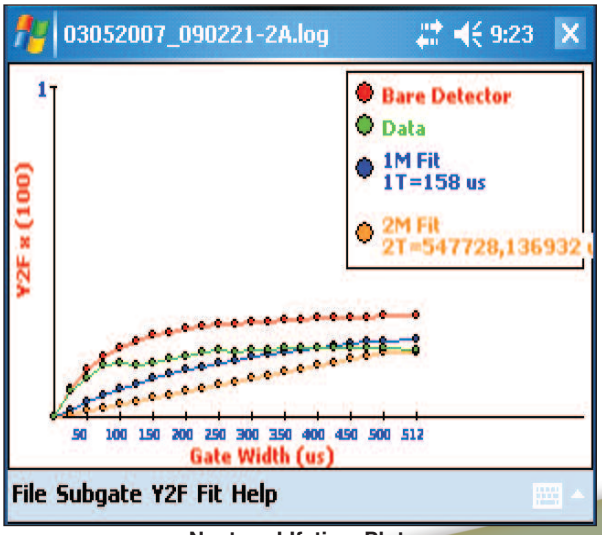
The second plot is the neutron lifetime which can help the detection of moderation material (e.g., polyethylene shielding).



Characterization Data Collect.



Multiplicity Plot.



Neutron LIfetime Plot.

***Where, How and Why to Submit Fission Meter Data for Expert Resolution of Smuggling Attempts**

The US Department of Energy (DOE) provides "reachback" radiological incident assistance 24 hours a day, seven days a week. Staff at the this center can arrange for further analysis of characterization data sets by DOE experts. In the first instance, the Fission Meter user should contact the DOE Emergency Operations Center (Phone (+1) 202-586-8100) and ask to speak with the Emergency Response Officer (ERO). The user will be placed in contact with the appropriate party within DOE to interpret the data and recommend appropriate action.

The US Domestic Nuclear Detection Office (DNDO) Joint Analysis Center (JAC), the Operations Support Directorate within DNDO is responsible for establishing and operating a real-time situational awareness and support capability by monitoring the status of, and collecting information from, both overseas and domestic detection systems through the Joint Analysis Center (JAC) and other programs. It is staffed with personnel from the Departments of Defense, Energy, Homeland Security, Federal Bureau of Investigation and the Nuclear Regulatory Commission. The JAC facilitates the information flow on radiological detection events between the interagency and State and local authorities. 24-hour emergency Hotline: 877-363-6522.

Fission Meter

Specifications

Ambient Operating Environment: 0°C to 40°C, at relative humidity: <90% at 35°C, non-condensing.

CE Compliance: Conforms to CE standards for radiated and conducted emissions, susceptibility and low voltage power directives (EN61326).

Weight

Without case: 52 lbs.
With case 59: lbs.
Shipping: 120 lbs.

Dimensions

Without case
- Folded: 18 in. L x 4.5 in W x 26 in H
- Unfolded: 39.25 in L x 2.25 in W x 26 in H

With case
- Folded: 19 in L x 6.25 in W x 26.5 in H
- Unfolded: 39.5 in L x 3.125 in W x 26.5 in H

Ordering Information

Model	Description
FM-P3	Portable Fission Meter System. Includes 30 each ^{3}He detectors at nominally 7.5 ATM pressure, multiplicity electronics, rugged hand-held computer (TDS Ranger), Fission Meter software and waterproof nylon carry bag for protection of the detector panels.
FM-OPT1	Replacement Desiccant. Set of 8.

Specifications subject to change
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