NukAlert™ Technical Brief

The NukAlert™ Radiation meter and alarm

A resource for the restoration of civil defense in America

In the Aftermath of World War II, with the images of bombed out cities and the depravity of man fresh in everyone's mind, a state of the art civil defense program developed in tandem with the beginning of the Cold War. Then, in the 60s the concept of Mutually Assured Destruction (MAD) rendered civil defense politically incorrect. By the 80s, scientific propaganda suggested that the use of nuclear weapons would end life on Earth and would therefore never be contemplated by anyone. By the 90s civil defense was so anathema as to be considered immoral. The last vestiges of America's civil defense program were destroyed or sold as scrap by the first Bush and the Clinton administrations. While America disarmed and rendered its civilian population defenseless, our potential enemies continued the development and deployment of advanced nuclear weapons and prepared for their civilian populations to survive and win a nuclear war. We now face a wide variety of radiological threats, including Radiological Dispersal Devices and Improvised Nuclear Devices, in addition to the possibility of military, industrial or utility accidents.

Design Goals

The NukAlert™ is an attempt to make radiological protection and education again available to the American people. Low cost, ruggedness, zero maintenance, and a simple user interface were the primary design goals. The unit is designed to respond only to acute radiation hazards. Monitoring of occupational radiation levels should be done with more sophisticated instruments. A perfect radiation measurement instrument would have high sensitivity, instant response, uniform energy sensitivity, low battery consumption, low cost, ruggedness, and environmental immunity. Such an instrument does not exist. All existing instruments involve tradeoffs in some of the above qualities. Geiger Muller tubes are delicate, saturate at low radiation levels, and require battery consuming high voltage power supplies. Ionization chamber detectors produce extremely weak signal levels that require expensive and environmentally sensitive electronics. Scintillation detectors require large crystals of exotic materials and delicate electronic components. Photodiode detectors are expensive and have large temperature sensitivities.

Device Description

The patented NukAlert™ sensor also has strengths and weaknesses. It is composed of a Cadmium Sulfide Photoconductive cell viewing a Gadolinium OxySulfide scintillating phosphor through a custom molded plastic lens. The phosphor glows with a dim green light when exposed to radiation. Light emitted by the phosphor causes a reduction in the electrical resistance of the Cadmium Sulfide crystals in the photoconductive cell which the microprocessor measures to determine the radiation intensity. The main advantages of Cadmium Sulfide as the sensitive element are ruggedness, low cost, and low battery consumption. Its disadvantages are slow response and sensitivity to temperature changes. Cadmium Sulfide sensors exhibit a very slow (hours) response to faint light after prolonged darkness. To produce a faster response the NukAlert™ sensor is illuminated by faint flashes of light from a green light emitting diode when it is not alarming. This bias light is continuously adjusted by the microprocessor to maintain the sensor near the first alarm threshold. The bias illumination is turned off as the unit approaches alarm so that calibration is not affected by it. At higher radiation intensities, the response of the sensor becomes more rapid. The early production NukAlerts™ had a very thin lead film over the sensor which limited the low energy response to 20KvP. Present production units without the lead film respond below 17KvP.

The NukAlert™ sensor is affected by changes in temperature. The sensor becomes less sensitive while cooling and tends toward alarm while warming. This effect is transitory and equilibrium will soon be established even after very large temperature changes. The selection of the bias point is a tradeoff between speed of response to low level radiation and susceptibility to temperature induced false alarms.

The chirp tone is a sweep through the audible range attempting to cover frequencies that almost everyone can hear and passing through the resonances of the housing. The loudness is set at a conversational level of 61dBA. This sound pressure level is a compromise between audibility and low temperature battery life. The birdlike sound is also chosen to be least threatening to children who might have to hear it for long periods of time in a shelter situation.

The NukAlert™ includes a monitor feature to assure the user of proper operation. In the normal quiescent mode a faint double tick (~every 5 seconds) is generated each time the sensor signal is sampled, indicating a functional unit. The flashing of the bias LED is indicated by a skipped tick. As the unit approaches the first alarm threshold, a more accurate measurement algorithm is enabled, the bias LED is disabled and the sound changes to a rapid ticking (~2 ticks per second). In the alarming mode, the sampling is done immediately before each chirp sequence followed by a delay that is progressively shorter as the number of chirps per sequence increases. The current production devices produce a rapid ticking between chirp sequences.

# of chirps per seq.	Delay between sequences sec.
1	30
2	25
3	18
4	13
5	8
6	7
7	6
8	4
9	2

The user interface incorporates the simplest and most easily understood logarithmic scale. Beginning with single chirps at about 100mR/hr, repeating chirp sequences indicate the radiation intensity. Each additional chirp in the sequence represents a doubling of the measured radiation.

# of chirps per seq.	Radiation level R/hr
1	0.1
2	0.2
3	0.4
4	0.8
5	1.6
6	3.2
7	6.4
8	12.8
9	25.6
continuous chirping	51.2+

Although the thresholds are printed on the label to three significant figures for ease of understanding, the threshold accuracy is generally plus double to minus one half. The response time required for the NukAlert™ to begin alarming and achieve its final alarm indication is an inverse function of the radiation intensity. The response is also exponential. For example it may take one minute to reach 63% of the final alarm reading, another minute to reach 86%, another minute to reach 95%, etc. In a 1R/hr field the unit should begin chirping in less than 1 minute, and reach the 4 chirp final response level expected of at 1R/hr within 5 minutes. Though this seems like a long time, the user has an indication of the hazard fairly quickly and the total absorbed dose is less than 0.1R. The response is a bit slower with weaker fields and faster with stronger fields. The NukAlert™ is about twice as sensitive to the midrange gamma energies expected in a nuclear fallout situation than it is to low energy X-rays (below 70KVp), or high energy gamma (above 1 MeV). The printed calibration label defines the approximate response to 660 KeV gamma photons from Cesium 137. The unit function may be easily verified by radiation from a dental x-ray machine. Position the unit as if it were a bite wing film and set the machine for a typical molar bite wing exposure. The unit should respond within 35 seconds after the exposure with a 4, 5, or 6 chirp alarm sequence that requires several minutes to ramp back down to silence (some digital dental units produce considerably less radiation).

Calibration Verification

To verify the calibration of the NukAlert™, the radiation intensity thresholds between each alarm level must be identified. This can only be done by bracketing the exposure intensity above and below the point at which the alarm indication changes. The unit should be at temperature equilibrium and sufficient time allowed for the unit to settle with each radiation level change. The NukAlert™ has a slower response to low radiation levels than traditional instruments. This must be considered when evaluating the device. The energy distribution of the beam must be considered, as the midrange peak in energy sensitivity will cause apparent non-linearity if lower energy scatter varies with the source to detector distance. The NukAlert™ measures a very broad range of radiation intensity. This presents a real challenge if an attempt is made to test the entire range. The source must be strong enough so that it is not closer than about one foot from the unit for any measurement. The volume of the reference instrument should be no greater than 1ml and it should be the same distance from the source as the sensor inside the NukAlert™. The NukAlert™ calibration is not greatly affected by temperature. It is, however, affected by changing temperature. As the temperature is increasing, the unit is oversensitive and while decreasing, under-sensitive. The rapidity of temperature changes determine the magnitude of this effect. Very rapid increases in temperature will cause the unit to alarm briefly until equilibrium is established. If an attempt is made to measure the response time of the instrument, the alarm threshold of interest must first be identified. The unit, after a rest period, should then be exposed to a field 50% greater than the measured threshold while the time to reach the alarm indication is measured. The response time is progressively shorter at each higher alarm level.

The Lithium battery in the NukAlert™ is a 1,000mA-hr coin cell. The self discharge at room temperature is less than 1% per year. The battery manufacturer guarantees a ten year shelf life. The computer in the NukAlert™ spends most of its time in a sleep mode drawing less than 1 microamp. The computer is turned on to make a measurement up to 5 times per second drawing about 300 microamps for less than 100 microseconds. The average drain = 300 microamps X 0.0005 duty cycle = 0.15 microamp. So, the average drain of less than 1.15 microamp divided into the 1,000,000 microamp hour battery capacity = 666,667 hours = 76 years. Clearly ten years is a conservative estimate. There are other factors entering into the battery life calculations yielding a worst case life of 18 years. Even with the alarm sounding continuously (over-range mode) the average battery drain is only about 750 microamps. 1,000,000microamp-hours/750microamps = 1333 hours = 55 days. At the one chirp alarm level, the duty cycle is about 0.03. Thus at the one chirp alarm level the battery will last about (1,000,000 microamp-hours)/(0.03 X 1250microamps) = 26,667 hours = 3 years.

The NukAlert™ has been tested by the Naval Air Warfare Center for Electromagnetic Pulse immunity and meets MIL-STD-461D, RS105. It has also passed FCC and EU testing for electromagnetic compatibility.

A final note:

The NukAlert™ is intended as an ever present 24/7 early warning device. It is also useful in determining the relative effectiveness of shelter. Its calibration and readout are clearly approximate. If one needs precise measurements for the micro-managing of radiation exposure, or an instant response to very low radiation levels, other types of instruments should be chosen to augment the NukAlert's™ capabilities. Even though the unit does not give highly precise measurements, a rough footprint of a high level radiological event could be obtained from first responders carrying NukAlerts™. Effective distributed detection could be achieved by equipping first-responders, postal carriers and other civil servants with the device.