SOFTWARE FOR MINIMIZING DETECTOR COUNT TIMES AND LOGGING FSS DATA

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ABSTRACT

This Surface Survey Controller (SSC) is designed to automate hand held surface activity measurements. The SSC is a software-based system integration tool that controls all operational aspects of the measurement process, including reliability of detection, false positive rates, and data base records. The concept behind the SSC is to regulate, to the maximum extent feasible, the variables that would otherwise reduce the accuracy and precision of surface contamination measurements, while increasing productivity. The users specify parameters such as minimum detectable activity, the probability of falsely concluding that the item is contaminated (Type I error), the probability of falsely concluding that the item is not contaminated (Type II error), material background values, spot contamination limit, or wide area contamination limit. The software runs on a personal digital assistant (PDA) that is attached to a customized counting card and a suitable detection probe.

The control software considers the number of measurements that will be made, the required sensitivity, the detector parameters (efficiency, background), the specified error rates, and the desired contamination limits and determines the counting time and automatic verification range.

During the measurement process, the SCC notifies the operator if contamination is detected above the spot contamination limit. When the total number of measurements for an object or area is complete, the SSC will indicate to the operator whether contamination was determined to be present at or above the area contamination limit and whether the sensitivity was adequate. If the area sensitivity was not adequate, the SCC will require that the area be recounted. The SCC conducts a statistical evaluation according to *t*-test or other applicable statistical criteria. The result is displayed on the control panel and a record of the survey is created.
The SSC maintains database records of all measurements. The database can be queried to extract detailed records or summary reports. A graphic display interface provides status to the operator.

INTRODUCTION

This presentation describes a new concept for hand held monitoring systems, called the Surface Survey Controller (SSC), which is designed to automate hand held surface activity measurements. The SSC is a software-based system integration tool that controls all operational aspects of the measurement process, including reliability of detection, false positive rates, and data base records. The concept behind the SSC is to regulate, to the maximum extent feasible, the variables that would otherwise reduce the accuracy and precision of surface contamination measurements, while increasing productivity. The users specify parameters such as minimum detectable activity, Type I and II error rates, material background values, spot contamination limit, or wide area contamination limit. The software runs on a PDA attached to a compatible counting card and a suitable detection probe. The operator would input the calibrated efficiencies of the detectors, conduct background counts and response checks, and identify the item or location of the survey. The SSC and the cognizant engineer would then control variables such as:

- Temperature & high voltage
- Measurement time
- Sensitivity & quality objectives
- Number of measurements
- False positive and false negative errors
- Automatic verification of suspected contamination
- Flagging contamination in excess of action levels
- Data logging.

The operator of the SSC, having input specifications for the survey, and having conducted background measurements and operability checks, then surrenders control of the actual measurements to the SSC’s software. The design of the software allows the SCC to directly measure the average background count rate as well as the estimated variance (sigma) in the background count rate.

Control Software

The control software considers the number of measurements that will be made, the required sensitivity, the detector parameters (efficiency, background), the specified error rates, and the desired contamination limits. The algorithms return values for the counting time and automatic verification range. The control program conducts a two-stage measurement process using static measurements. The first stage measurements are conducted for the minimum time required to achieve the Type II error rate. In the second stage of measurements, the software addresses measurement values that fall within an automatic verification range. The upper and lower bounds of the automatic measurement range are determined by the software, with the lower bound being the critical level that achieves the Type II error rate and the upper bound being a value where a Type I error is no longer realistically expected. If the initial measurement falls within the automatic verification range, the SSC will repeat the measurement for a period of time sufficient to achieve the desired Type I error rate.

Statistical Evaluation

During the measurement process, the SCC notifies the operator if contamination is detected above the spot contamination limit. When the total number of measurements for an object or area is complete, the SSC will indicate to the operator whether contamination was determined to be present at or above the area contamination limit and whether the sensitivity was adequate. If the area sensitivity was not adequate, the SCC will require that the area be recounted. The SCC conducts a statistical evaluation according to *t*-test or other statistical criteria. The result is displayed on the control panel and a record of the survey is created.

The SSC maintains database records of all measurements. The database can be queried to extract detailed records or summary reports. A graphic display interface provides status to the operator.

The concept can be applied to hand held measurements. In this case, the technician must position the probe for each measurement and indicate such to the SCC control system. The SCC could also operate in a robotic mode, e.g. a mobile floor monitor.

Implementation

In each implementation, the SCC monitors critical parameters, conducts measurements sufficient for the time required to satisfy the specified sensitivity and error, and determine when sufficient measurements have taken to determine the presence or absence of contamination according to regulatory guidelines for clearance or final decommissioning status procedures. The SSC software contains a unified set of algorithms that calculate the shortest count time required to satisfy the given survey requirements. The key innovation in these algorithms is that the count time is a function of the number of measurements, the applicable statistical tests, and the area contamination limit, in addition to the parameters that normally constitute the equation for minimum detectable activity. The SCC system also includes a dedicated background comparison detector, so that all measurements are paired measurements.

The initial implementation of this concept is a series of monitoring systems designed for surveys of walls, floors and ceilings during D&D activities. These first systems use an array of six gas proportional alpha/beta detectors to perform static gross alpha and gross beta measurements of surface contamination. Two additional detectors provide paired background reference counts for the surface measurements. Each detector has a $100cm^2$ active counting area. Each detector is connected to a separate channel of a data logger, which provides a high voltage bias and collects alpha/beta pulses according to commands from the SSC software. The SSC software provides data collection and reporting functions, controls the radiation detectors, and manipulates the electromechanical components of the monitoring system. The SSC interfaces to the data logger through a terminal server and to the electromechanical components via a programmable logic controller (PLC). In use, the SSC measures the ambient temperature and adjusts each detector's high voltage setting to maintain the efficiency recorded during calibration.

Control Algorithm

The heart of the monitoring system, however, is a set of algorithms that control the statistical reliability of the data and ensure that a sufficient number of measurements of adequate duration are collected. The algorithms apply systematic survey planning and quality objective protocols to determine the presence or absence of contamination at the sensitivity value provided by the user. The algorithms operate on two levels: the individual measurements of 100 cm^2 areas, and the monitoring of wide areas, which may be from 0.25 m to 100 m in area.

In a typical application, individual measurements are controlled by calculating the time required to satisfy minimum detectable activity (MDA) criteria with a 10% to 50% probability of Type I (false negative errors) and a 1% probability of Type II (false positive errors) when contamination is present at the derived concentration guideline level for elevated measurement concentrations in small areas ($DCGL_{emc}$). The SSC applies a two-stage screening process to recount initial measurements that contain the $DCGL_{emc}$ within the 95% confidence level of the initial measurement. That is, if the initial measurement could result in a value exceeding the $DCGL_{emc}$ in more than 5% of repetitions, the measurement will be repeated with a higher precision. The recount time is calculated to reduce the false positive rate after the recount to less than 1 occurrence in 100,000 measurements.

Area measurements are controlled by determining the number of measurements that will be taken in each area and adjusting the initial count time, if required, to ensure that the number of measurements is adequate to determine the presence or absence of contamination at the derived concentration guideline level for the wide area average concentration in a survey unit ($DCGL_w$) at the 95% confidence level according to *t*-test or other applicable statistical tests. The SSC completes a report for each survey area which indicates the average and range of the measured contamination and highlights cases that exceed the $DCGL_{emc}$ or $DCGL_w$.

This control logic ensures that each area will be automatically measured for the minimum amount of time needed to statistically determine the presence of contamination at the stated control level.

Static Measurements

All measurements are static. The SSC does not count while the detectors are moving to eliminate the potential for background noise from electrical motors. The typical minimum detectable activities are approximately 20 dpm/100cm^2 total alpha, 100 dpm/100cm^2 total Sr-90, and 500 dpm/100cm^2 Tc-99 averaged over one square meter. The sensitivities for discrete 100cm^2 spots of contamination are typically five times the average values for a square meter.

Application

A floor monitor, called the Final Survey Monitor (FSM) has been developed as a practical implementation of this concept. The FSM is a computer-controlled system that uses mostly off-the-shelf components to reduce capital costs and simplify procurement of spare parts. The detectors are Ludlum Model 43-68 gas flow alpha-beta proportional probes in a gas flow mode. This rugged, dependable, 100 cm^2 design has been used and/or specified in many D&D projects, including Ft. St. Vrain, Rocky Flats, and Maine Yankee. The FSM uses a modified Ludlum Model 2360 counting card that is networked directly to a PC through a terminal server.

There are eight detectors: two are used for background monitoring and as installed spares; six detectors are used to sweep a one meter-wide strip of floor or wall. There is a gas distribution manifold that monitors the return gas flow from each detector and provides an alarm signal to the computer if any detector has inadequate gas flow. The computer monitors the detector status, gas flow rates, background count rate and temperature, then adjusts the count time and high voltage setting of the detectors to achieve the MDA and initiates a measurement. All measurements are performed in a static mode. The computer reviews the initial counts and immediately recounts any spots that returned ambiguous count values ("gray area"). This typically allows for 90+% reliability of detection of the MDA value. The computer then automatically moves the detector array to the next position for another measurement. There is 8% overlap between the measurements to ensure 100% coverage of the surface area. The computer scans a one-meter square area, prints a report if desired, and immediately begins sweeping the next square meter. Data can be stored on a floppy disk, CDROM or transferred to a laptop via wireless LAN (optional). The FSM can also survey fractions of a square meter.

The report shows the alpha/beta activity of each 100 cm^2 spot, the average for the square meter, and the highest activity spot. The computer shows the status of each measurement on a real-time display. The screen can page backward to review previous measurements. The FSM can reduce survey costs several ways:

The FSM will survey ~70 square meters per hour for Tc-99 at 1" calibration with 600 cpm background per probe and an MDA of 5000 dpm and ~98% reliability. A 10 cm wide probe scanning 5 cm(~2")/sec will sweep ~18 square meters per hour.
The FSM will survey 100+ square meters per hour for a typical final site survey (FSS) limit of 18,000 dpm (~7,000 detectable at 13% efficiency) with 600 cpm background.
For FSS activities, the "gridding" can be reduced to "lining" with tic marks, which reduces the cost of preparation.

The FSM also reduces uncertainty because NRC, DOE and EPA criteria are generally specified in units of activity per 100 cm^2 averaged over one square meter. These are exactly the quantities measured by the FSM. And the control software ensures that an adequate number of measurements of sufficient duration have been taken to resolve the presence or absence of the specified contamination level and reliability. There is no uncertainty in the results, because the required measurements were obtained and documented legibly.

A hand held unit was also designed, using similar control algorithms, that operates with Geiger-Mueller, scintillation or gas proportional probes. The floor monitors and the hand held monitors can merge survey data for a given survey unit into a single data base.

Quality Control

The QC function of the data acquisition system receives count measurements from each data logger channel and screens the data for positive results. Positive results that exceed an action level established by the user (for example: >5000 dpm alpha per probe area or >500 dpm/100cm^2 averaged over 1 m^2) are flagged. Audible alarms can be generated at the option of the user. Spots of contamination in the range of the user-defined "gray area" are immediately recounted to eliminate false positives. High average contamination is immediately displayed and reported to facilitate a verification recount for false positives. The QC function also monitors each detector to ensure that minimum count rates are collected. Insufficient count rates are flagged to facilitate a verification recount for false negatives.

Results

Figure 1 presents results from a final status survey measurement program during the period of time when the handheld SSC was first placed into actual service in an FSS program. In this application, the handheld SCCs were used to monitor residual surface contamination on steel and concrete structural elements in a private industrial facility survey program. No scanning was conducted. All surfaces were 100% surveyed with static measurements, using LM 43-68 and LM 43-37 probes, and each measurement result was recorded. In this case the quantities designated by yellow triangles designate actual quantity surveyed each day (square feet per day). During the period of time up to April 3, the program that was written to upload automatically logged measurement results into the main computer database on the server was corrupted and data were not being uploaded electronically. The data were recorded by hand and entered into the database by hand. The survey productivity was therefore analogous to a typical protocol for recording and entering data by hand.

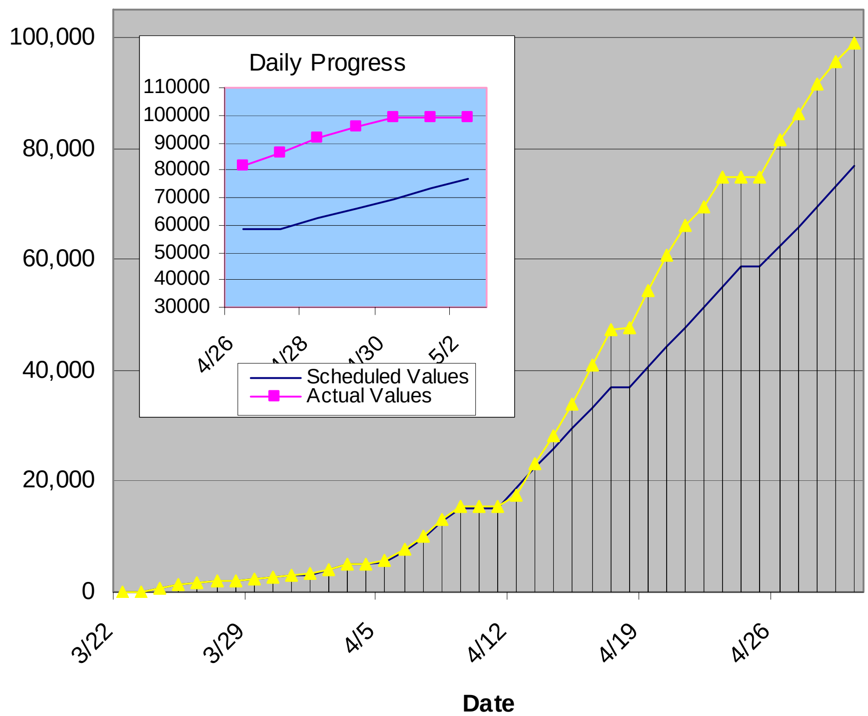

Fig. 1. Productivity

Beginning on April 4, the blue line on the chart shows the projected productivity that was originally estimated for automated data collection versus the actual rate (yellow points) at which surface contamination data were collected and accumulated in the database. During both periods, the posted data collection rates are net of rework items. The procedure in placed required that all data be reviewed by a radiological engineer prior to acceptance. Data of dubious quality, duplicates, and incomplete survey data were not included in these totals. The insert in Figure one shows a detail for a one-week period. No data were collected on weekends.

The data clearly indicate a significant increase in productivity beginning on April 5. It is important to note that the change in survey completion rate was not related to changes in the number of technicians, quantity of survey instruments, location of items being surveyed, or other confounding factors; the only significant change was eliminating the need to record and reenter measurement results by hand.

During the period from April 4 to April 9, the projected survey rate and the actual survey rate are exactly matched. This occurred because the work planners were loading the daily quota of surveys into each SCC according to the schedule and the technicians were able to complete all of their assigned surveys each day because the automated logging function was now operable. When the project manager realized that the productivity was higher than the scheduled rate, the work planners were instructed to load survey requirements into the units at a higher rate. By April 14, the survey productivity was running 50% above the scheduled rate and approximately eight times faster than using a hand recorded process.

In addition to the automated data logging, the SCC calculates the shortest time required to satisfy the sensitivity and reliability criteria that are imposed on each measurement. Typical programs use a fixed count time that is adequate to satisfy the boundary conditions. The SCC dynamically adapts to the probe efficiency, material background, and ambient background so that measurements satisfy all sensitivity requirements when the actual radiation levels are approximately equal to the action level limits. The SCC operates with a two step counting process that automatically verifies measurements when the action level limits are with the 95% confidence interval of the measurement. Typically survey procedures require recounting results that exceed the limit, but the SCC program recounts every measurement that contains the action level within its 95% confidence interval. As a result, the standard deviation of individual measurements may be relatively high, but only when the observed radiation levels are significantly lower or significantly higher than the action level limit. Figure 2 shows the standard deviation of a set of actual field measurements that range from 300 to 18,000 cpm. In this system, a gross count rate of 4,000 cpm corresponds to an action level limit.

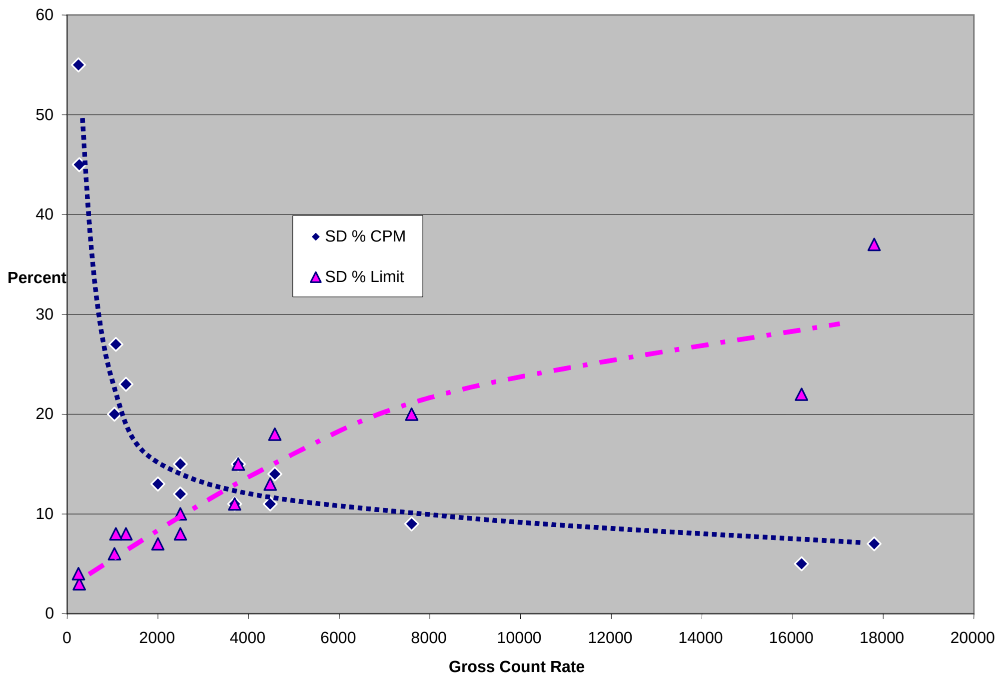

Fig. 2. Observed standard deviation as a percentage of count rate and residual limit

The figure shows that when gross count rates are near background levels, the standard deviation of the measurement approached 50% of the count rate, but when the gross count rate increased to values near the action level limit, the standard deviation of the measurement in the range of 11% to 15% of the action level limit. Therefore the SCC optimizes the count time for the few measurements that are near the limit and allows less precision where the quality of the survey is not impacted.

CONCLUSION

A microprocessor based survey controller is able improve survey efficiency by minimizing hand recording efforts and optimizing the count time of individual measurements.